WATER POWER

A technical journal devoted to the study of all aspects of Hydro-electric developments

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Owen Falls Many miles of power, distribution and control cables for the first section of this great scheme were supplied and installed for the Uganda Electricity Board by the BICC Group, who are also erecting 120 miles of 132kV overhead line to carry power to Tororo and Kampala.

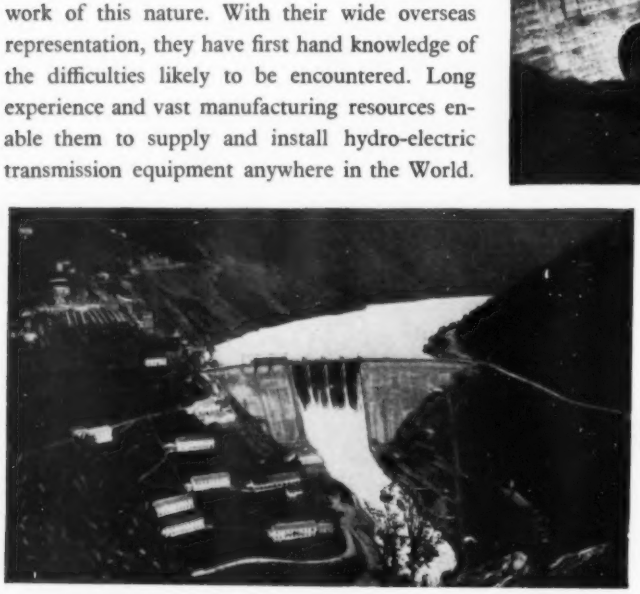
Consulting Engineers:
Sir Alexander Gibb & Partners and Messrs. Kennedy & Donkin.

3 Major Hydro-Electric Schemes

USING BICC TRANSMISSION EQUIPMENT

No two hydro-electric schemes are identical. Each presents a new set of problems to the transmission engineer, for terrain, climate and location are all important factors in the design, supply and installation of transmission equipment.

That is why BICC are so often employed on work of this nature. With their wide overseas representation, they have first hand knowledge of the difficulties likely to be encountered. Long experience and vast manufacturing resources enable them to supply and install hydro-electric transmission equipment anywhere in the World.



Loch Sloy This scheme is now connected with the Clachan power station of the Glen Shira Hydro-Electric Scheme by a nine mile single circuit 132kV overhead line. It was erected for the North of Scotland Hydro-Electric Board by the BICC Group. *Consulting Engineers:* Messrs. Merz & McLellan of London.

Los Peares At Los Peares, Spain, Fuerzas Electricas del Noroeste S.A. (Fenosa) have erected a dam and a 160,000kW power station. Approximately 20 miles of BICC multicore control cables were used in this contract. They were supplied through our agents in Madrid, Dugopa S.L., to the British Thomson-Houston Co., Ltd.—main contractors.

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WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

The Work of the B.H.R.A.

LAST month's annual Open Days of the British Hydromechanics Research Association, when nearly 400 technical visitors were welcomed to the Harlow laboratories, conveyed a reassuring impression. Evidently the Association is well past the "raw" stage that must always be lived through when a new organisation is getting under way, and has settled down smoothly to its appointed task of providing a joint research and information service to British manufacturers of hydraulic equipment. Indeed, it has extended its boundaries, for in spite of the word "hydromechanics" in its title, the Association is interpreting the term "fluid mechanics" in its widest sense and is doing important work for the oil companies and on mine ventilation, as well as hydraulic coal transport, for the National Coal Board. Further, it is assisting non-members through the Conditional Aid Scheme for the use of Counterpart Funds derived from United States Economic Aid.

From our own standpoint the most interesting series of investigations in hand is that of model tests on spillway structures. Here the Association has the satisfaction of knowing that some of its earlier work has borne fruit, for the Weir Wood reservoir for the sister town of Crawley is now in operation and was recently officially opened by the Duke of Norfolk. A few years ago a model of the bellmouthed spillway for this reservoir was tested at the laboratory, and the final design incorporated features found to be desirable in the light of these tests.

A 1 : 200 scale model of a spillway for one of the great African hydro-electric schemes is now undergoing trials, comparative tests being made with radial-gate and bottom-sluice types of spillway. There is also a 1 : 50 scale model of the side-channel weir and by-wash channel for the Hurst reservoir and a 1 : 60 scale model of the overflow weir, stilling pool and gauging weir for a dam on the Devonshire Avon. We understand that the tests on the last-named model have pointed the way to a substantial reduction in construction costs.

Important fundamental work is being carried out on the design of centrifugal pumps. The design of pump suction sumps has engaged much attention, as the performance of a pump has been found to be profoundly influenced by the design of its sump. As regards the design of the centrifugal pump itself the impeller and the volute are being studied both separately and together in order to trace the actual flow patterns obtaining and to locate the sources and amounts of the various losses incurred. The study of flow in an impeller is being studied by two methods. The first employs air as the fluid (the results, of course, being suitably rescaled) and uses an impeller with restricted suction and discharging freely into the atmosphere, the velocity and direction of the fluid at various points in the vane passages being determined by hot-wire anemometers. At some distance within the passage the flow pattern approximates to the theoretical, the flow angle being approximately constant and the highest velocity occuring near the suction face of the vane; but near the periphery of the impeller the velocity close to the suction face diminishes and random turbulence is severe.

It will be interesting to learn how far this breakdown of the flow pattern obtains when the volute is in position and how far it may be due to the discharge into a comparatively stationary atmosphere. The answer to our query may eventually be found in an accompanying series of investigations on an identical impeller operating within a volute and also using air as the operating fluid. This series is planned to compare the total head emerging from the impeller in its volute with the head generated by the same impeller discharging directly to atmosphere, to study the mixing process whereby the velocity emerging from the impeller diminishes to the mean velocity in the volute, and to determine the magnitude and causes of the energy losses taking place in the volute and delivery branch.

The second method of studying flow in the impeller is intended as a check on the air method. An identical

model of the impeller has been made in transparent material and is rotated in a large cylindrical tank fitted with windows at top and bottom. Small solid spheres of a mixture of wax and stearate of unit specific gravity are introduced into the flow and their paths recorded photographically. A section of a high-speed cinematograph film was demonstrated.

These investigations on the flow in centrifugal pumps impress us as being of great potential importance, and we trust that they will bring worthy results.

Although it is outside our field, mention should be made of the important work which the Association is carrying out for the National Coal Board on the hydraulic transport of coal. Basic work on this problem has been going on at the laboratory for some considerable time, and an experimental three-cylinder feeder has now been built designed to lift 50-100 tons of coal per hour to the surface of a 500 ft. mine. This machine will shortly be installed in an East Midlands colliery. A single-cylinder prototype has been operating successfully for some time at Wood End colliery, near Edinburgh.

Work is continuing on glands and seals and on the characteristics of disc valves, and those concerned with servomotor mechanisms will be interested in the investigation on hydraulic lock, which is being carried out at pressures up to 10,000 lb. per sq. in.

At its Open Days the Association seems to be forming the very agreeable habit of including a novelty among its exhibits. This year we were treated to an eight-shaped perspex tube filled with water, in which, for no obvious reason, a number of British coins of the realm performed a species of motor-cycle race, complete with occasional crashes. Apparently no soul-shaking scientific principle was at stake, but it delighted the schoolboy in all of us.

East Kilbride Hydraulics Laboratory

THE Hydraulic Machinery Laboratory of the Department of Scientific and Industrial Research at East Kilbride, Glasgow, is now nearing completion and has already gone into use. It has been built for the use of the Fluid Mechanics Division, one of the seven sections of the D.S.I.R.'s Mechanical Engineering Research Laboratory. The building houses basic and applied research on problems relating to industrial practice, ranging from low-speed aerodynamics and hydraulics to the complex fluid-flow problems arising from intensified industrial progress. The sections already in use include the aerodynamics laboratory and the oil and special fluids laboratory; special open and closed circuits are being provided for research work on pumps, turbines and allied equipment, including valves, pipes and ducts. Other sections will deal with cavitation and calibration of flow-measuring instruments.

The work already done is indicative of the long-term approach to these problems. Since 1949 when staff was largely recruited, work has been proceeding on the basic problems of the design of the laboratory to ensure that it would be one of the most efficient and modern in the world and fully capable of meeting the duties involved. Similar installations in the U.S.A. and elsewhere were studied before the laboratory designs were finally approved. Even yet, although the actual building is nearly completed it will be still some two years before all the instruments and equipment have been installed and put into use. Coincident with this programme the staff has been engaged on preparatory research work as well as on day-to-day co-operation with industry in the solution of current problems.

The laboratory has its own water system, storing 200,000 gallons; filtration plant has been incorporated to make the water suitable for its work, and to facilitate underwater photography; in addition, special lighting has been incorporated in the sump and at observation points. Dr. D. G. Sopwith is in charge of the Mechanical Engineering Research Laboratory and the Division using the new hydraulics laboratory is controlled by Dr. S. P. Hutton.

Conference on Power from the Sea

A FOURTH Hydraulics Conference, to be devoted to the subject of power from the sea, is being organised by La Société Hydrotechnique de France, 199, Rue de Grenelle, Paris VII, and will be held in Paris from June 10 to 17, 1956. Both mechanical and thermal methods of power production will be reviewed. Consideration of mechanical means will fall under the two main heads of power from the waves and power from the tides, each of which will be debated from three aspects—the natural phenomena involved, model tests, and practical utilisation.

During the first week-end of the Conference a visit will be paid to St. Malo to inspect the Rance estuary and a model of the proposed tidal scheme, and during the second week-end the Argentat and Cambeyrac stations will be visited to inspect prototypes of turbo-generators adaptable for tidal power.

Those desirous of presenting papers should indicate their intention to the Society without delay and submit a 10-line summary by January 1, 1956.

Steenbras Dam

A PAPER presented by S. S. Morris, B.Sc.(Eng.), M.I.C.E., M.Amer.Soc.C.E., and W. S. Garrett, B.Sc.(Eng.), A.M.I.C.E., to The Institution of Civil Engineers dealt with the raising and strengthening of the Steenbras dam which forms the main source of Cape Town's water supply. An analysis of a number of alternative methods showed that the Coyne process of anchoring the dam by post-stressing would have every advantage both in cost and expedition.

The process consists of placing vertical cables through the wall of a mass-concrete dam from the crest into the foundation and stressing the cables to produce stabilising compressive forces on the upstream face. The principal items of construction were drilling the ducts for the cables, homing in the cables, and anchoring and tensioning them. The most interesting design problems were the determination of the required depth and length of the cable anchorages, for which semi-empirical methods were used.

Extracts from the specification covering the vital operations of drilling and placing, and the tensioning of the cables were quoted, also a brief description was given of the manner in which the work was actually executed.

Because of difficulties created by obstructions in the dam wall and the alternating character and dip of the rock foundation, percussion replaced diamond machines for most of the drilling. Homing-in of the cables presented little difficulty, but grouting for

anchorage posed a number of problems. Extensive full-scale experiments were carried out before the method finally adopted was developed.

In spite of inevitable constructive hazards work proceeded satisfactorily close to programme and was completed in time to store additional winter water. The project has been proved an unqualified success from every angle. Indeed, sale of the additional water which raising of the Steenbras Dam made available to Cape Town in the first summer after completion of the work more than sufficed to cover the complete cost of construction.

Messina Cable-Stringing Completed

THE stringing of the cables over the Messina Straits between Italy and Sicily has now been completed, and the restrictions to shipping that it was necessary to impose have been withdrawn. The span of 3,653 m. is the longest in the world. The cables are suspended from towers 224 m. high constructed by Società Anonima Elettrificazione of Milan, and the insulator strings, designed for loads of 50,000 and 75,000 kg., were supplied by Società Elettro Morsetterie Volpato, Milan. At present four 27·8 mm. ACSR conductors are employed, and as a first stage the line will operate at 150 kV and will have a capacity of 50 MW. Insulation has been designed, however, for 220 kV, and at this voltage it will be possible to handle a capacity of 150 MW. It is proposed ultimately to string two further conductors, bringing the final capacity of the line to 300 MW.

The project has been financed by Italian electric utility companies with assistance from Società Generale Elettrica della Sicilia, and will form the link in a network connecting Messina, Catania and Palermo in Sicily with the system of Compagnia Nazionale Imprese Elettriche on the mainland.

An abstract giving some further constructional details appears on page 437 of this issue.

Break-through at Dalchonzie

THE first break-through in the tunnels being driven by the Mitchell Construction Company of Peterborough on the Breadalbane project of the North of Scotland Hydro-Electric Board was achieved recently on the Dalchonzie section (16,226 ft.). This tunnel of 11 ft. 6 in. diameter will carry water from the river Earn to a generating station at Dalchonzie.

Work on both the east and west headings of this tunnel commenced in October, 1954, and the break-through after 11 months was 3½ months ahead of schedule, in spite of four soft patches, two at the west end and two at the east end, with a total length of 150 ft. The total footage driven from both ends was 16,226 ft., and allowing for the time that was taken by anual and trade holidays the average rate of progress on the downstream side has been 186 ft. per week and on the upstream drive 200 ft. per week, giving an overall average of 193 ft. per week. The total footage drilled was 134 miles 3,276 ft. and the total amount of explosive used 153 tons 13 cwt. of polar ammon gelignite. The average pull on the downstream face was 5 ft. 2 in. and on the upstream face 5 ft. 5 in. Tunnel spoil removed totalled approximately 75,000 cu. yards. Approximately 1,000,000,000 cu. ft. of compressed air at 100 lb. per sq. in. was delivered to the face, and the Ruston & Hornsby locos travelled approximately 10,000 miles.

Altogether the Mitchell Construction Company are driving 19 miles of tunnel on the Breadalbane project and the average rate of progress in recent months has been one mile per month. It will be remembered that a European record of 428 ft. of 9 ft. bed-width tunnel driven in one week was established by Mitchells on the Glen Almond section last Christmas.

The consulting engineers are Sir Murdoch MacDonald & Partners.

New Caledonia Plant

ESTABLISHMENT in New Caledonia of a hydro-electric plant to give 350 million kWh yearly has been approved by the General Council of the French Overseas Territory of New Caledonia. It will be financed by the fund for investment and economic and social development, and the estimate cost is over 29 million dollars. The output of the plant will be used by the local nickel mining industry. The nickel output of New Caledonia covers the major part of French nickel requirements but production cost is at present much higher than in other nickel producing areas. As a result of the installation of the new power plant, however, it is hoped that costs will be reduced so that prices will not exceed world prices.

Norway's Largest Project

WATERPOWER sufficient for a hydro-electric project with a capacity of up to 700 MW is available at Tokke, Telemark, in Norway, and the Norwegian Waterfalls and Electricity Board has plans ready for such a project. It is expected that the necessary appropriations for initial development work will be made as soon as a number of large power projects now under way are completed. The scheme, which involves installation of generators with a capacity of 100 MW each, will cost up to £40 million. An Electricity Board spokesman says the International Bank is very interested in the Tokke project, and it is hoped that negotiations now proceeding with the Bank will be successfully concluded this autumn.

Mr. Fulton Succeeds Mr. Lawrie at Scottish Hydro Board

THE North of Scotland Hydro-Electric Board have appointed Mr. Angus A. Fulton, F.R.S.E., B.Sc., M.Inst.C.E., M.I.Mech.E., General Manager in succession to the late Mr. Thomas Lawrie. Mr. Fulton has been the Board's Chief Hydraulic and Civil Engineer since 1944. He was born at Motherwell in 1900 and was educated at Dundee High School, University College and St. Andrew's University. After graduating he spent three years on the staff of Dundee Corporation Water Department before joining Boving and Co. Ltd., Hydraulic Engineers, London. On behalf of that company he carried out hydro-electric work in New Zealand, India, and South America. He returned to Dundee Corporation as Chief Assistant Engineer in the Water Department and in 1938 was appointed Engineer and Manager, a position he held until he joined the Board.

Fig. 12. A general view of Ruud power station

The Hol Developments

An important access to Oslo's power supply is being derived from developments on the Hallingdal river and its tributaries which will ultimately have a capacity of about 800 MW. In this second article we give details of the mechanical and electrical equipment at Ruud power station

PART TWO

IN our previous article we described the civil-engineering work involved in regulating the headwaters of the Hol catchment, and explained that the Ruud station, which we shall describe in this article, is supplied at two separate heads. The higher head is derived from the headwaters of the Votna, which are collected at Varaldsetvann at a maximum elevation of 1,005 m., giving, to the Ruud tailrace (598 m.), a maximum gross head of 407 m. The lower-head supply consists of the headwaters of the Hol and its tributaries, the Urunda and the Hivju, collected mainly in Strandevann at a maximum elevation of 974 m. (later to be 978 m.), giving a maximum gross head of 376 m., to be increased ultimately to 380 m.

The station will ultimately house four machines, two on each head, and a cross connection will enable one of the Votna sets to run at the lower head on Hol water. The Votna side of the station has been running since 1949, but the Hol side is still under construction.

The waters from the two catchments are brought by tunnel to separate surge shafts in the mountainside immediately above the power station. The general arrangement of these surge shafts and their adjacent valve chambers can be gathered from the sections through the Votna headworks given in Fig. 13 and detailed description is unnecessary. Water passes through trashracks to two penstocks, one for each machine, each penstock being equipped with two butterfly valves, one operated manually and the other automatically.

The Votna penstocks are 840 m. long, and each consists of an upper riveted section and a lower welded section, the latter being about 580 m. long. The upper sections were supplied by A/S Kvaerner Brug, Oslo. They are 2·2 m. in diameter tapering to 1·9 m. and constructed in 10 mm. to 21 mm. Siemens-Martin steel plate having an ultimate stress of 41-47 kg. per sq. m. For the welded sections, which were supplied by Bouchayer & Viallet, Grenoble, the diameter tapers from 1·9 m. to 1·5 m., and carbon-manganese plate of 48 kg. per sq. mm. ultimate stress is employed, ranging in thickness from 16 mm. to 33 mm. Erection was carried out by Erik Runde Mek. Verksted, Oslo.

Ten anchor blocks are provided for each penstock, and flexible supports are placed at intervals of about 16 m. Near the power house the penstocks enter a tunnel about 200 m. long and 34 sq. m. in cross section.

Three penstock outlets are provided from the Urunda surge shaft, the third being the cross connection to No. 2 penstock to enable the corresponding machine to be run on either Votna or Urunda water. The Urunda penstocks will be supplied by A/S Kvaerner Brug. Each will be about 770 m. long and will have diameters equal to those of the Votna penstocks. They will enter the power station by a separate tunnel.

The power house building is of reinforced concrete and covers an area of about 1,300 sq. m. The turbine draught tubes discharge into a tailrace tunnel of 30 sq. m. cross section and 220 m. long, leading to the Hol river in the bed of which a channel has been cut 350 m. long and 16 m. wide at the bottom.

Turbines

The two Votna turbines were supplied by A/S Kvaerner Brug. They were designed for an output of 60,000 h.p. at 500 r.p.m. at a net head of 385 m. but it has been found possible to rerate them at 65,000 h.p. at 390 m. head. When they were installed they were believed to be the highest-head Francis turbines in the world, but since then the builders have beaten their own record with the 69,000 h.p. turbines supplied to Vinstra power station, where the net head is

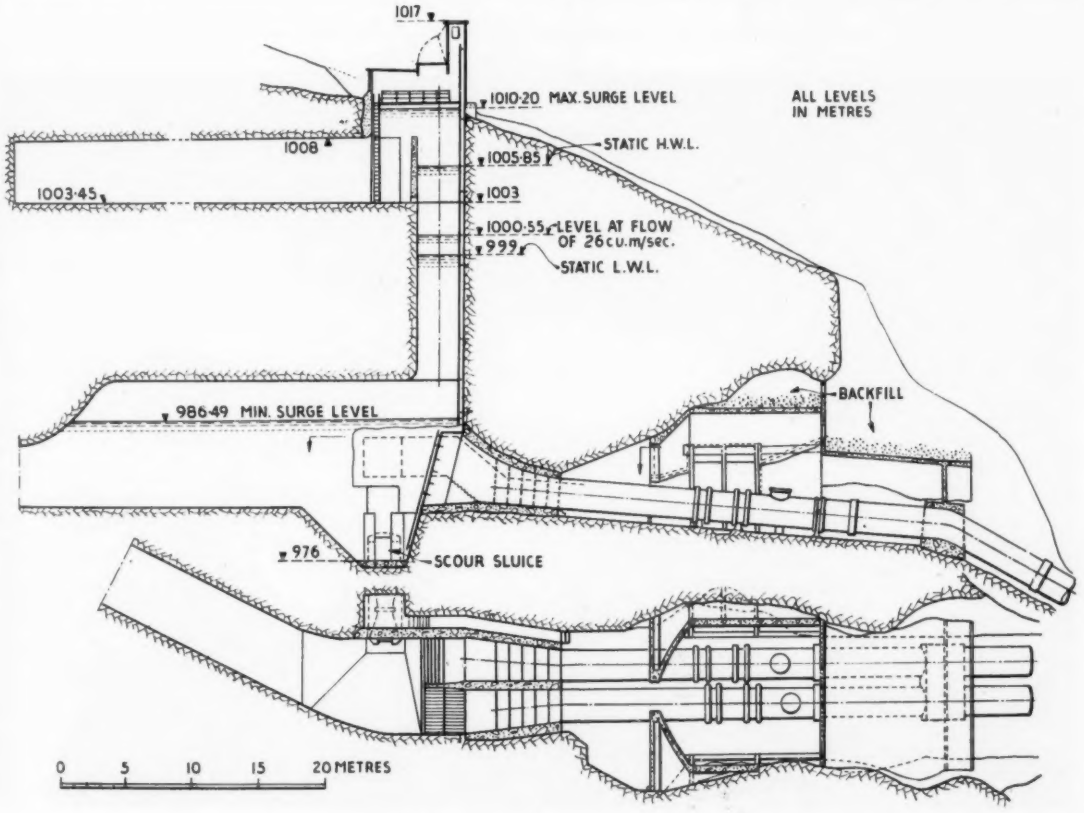


Fig. 13. Elevation and plan of the Votna surge and valve chambers

Fig. 14. Lining reinforcement in pressure tunnel near junction with surge chamber

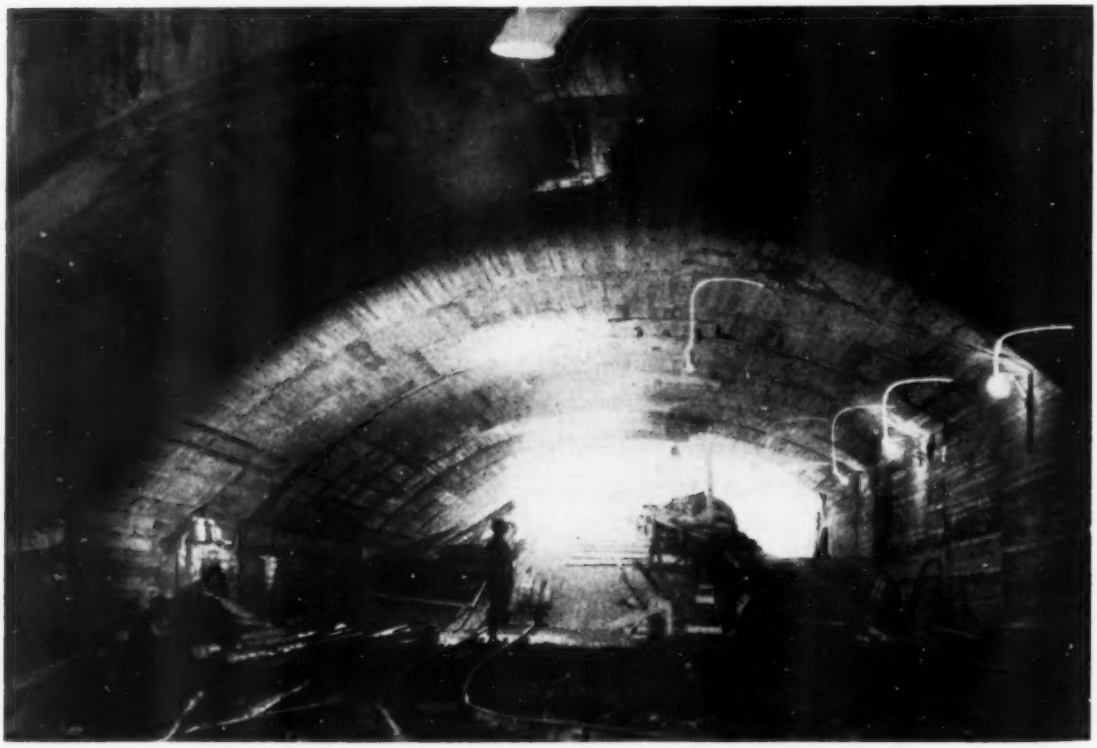


Fig. 15. Votna penstock tunnel looking from portal towards valve chamber

420 m.* We believe that since Vinstra was brought into commission certain Francis machines for still higher heads have been built in Europe, but this does not detract from the pioneer work that A/S Kvaerner Brug have done in the development of the high-head Francis turbine.

The decision to adopt Francis turbines in preference to Peltons was taken by Oslo Lysverker after a careful assessment of the technical and economic factors involved. It was estimated that the Pelton design would cost 25 per cent. more than the Francis design, taking into account the cost of turbines, generators, switchgear, transformers and buildings. The total saving with the Francis

* Vinstra power station will be described in a later issue.—EDITOR, WATER POWER.

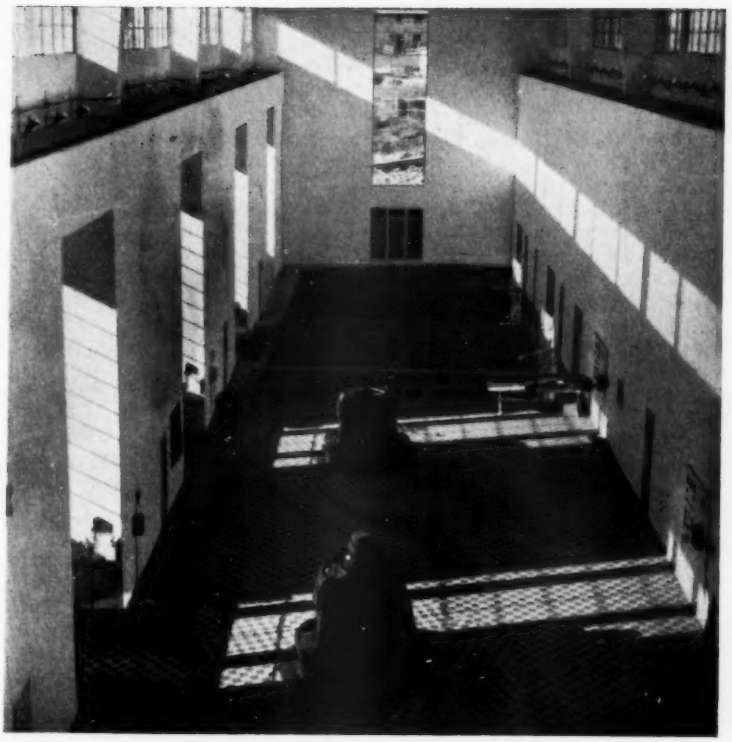
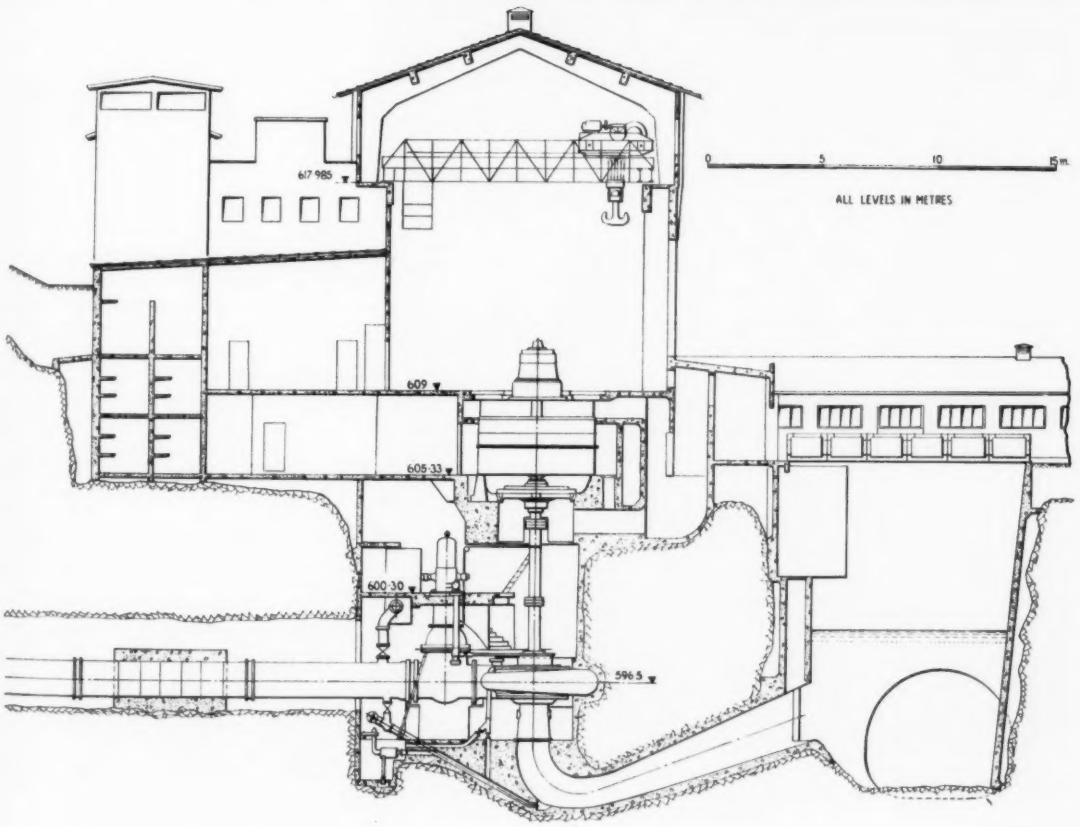


Fig. 16 (right). Ruud machine hall. The space for the Hol machines can be seen in the background

Fig. 17 (below). Section through Ruud power station, showing one of the Kvaerner / Brug / NEBB 65,000 h.p./50 MV A generating sets



was estimated at approximately 8 million kroner (£400,000). This saving is obtained mainly on account of the higher specific speed of the Francis turbine. Consequently it was computed that three 375 r.p.m. (Votna) and three 300 r.p.m. (Hol) four-jet Pelton sets would have been required for the proposed output as against the four 500 r.p.m. Francis machines actually decided upon. A second advantage is the lower runaway speed, which is 60 to 65 per cent. for the Francis as against 90 per cent. for the Pelton. This is reflected in the simpler and cheaper design of the generators. Thirdly, the efficiency of the proposed Francis turbines was expected to be about 92 per cent., and taking into account the head loss between a Pelton jet and the tailwater it was computed that there would be an improvement in maximum efficiency on the head available of about 3 per cent.

According to Norwegian experience, a Pelton turbine is rather more sensitive to sand and grit, but at Hol dirty water is no serious problem. On the other hand a more thorough clearing of penstock and intake is necessary before putting a Francis turbine into operation than for a Pelton. The power house for Pelton sets requires a greater floor area than for the corresponding Francis sets.

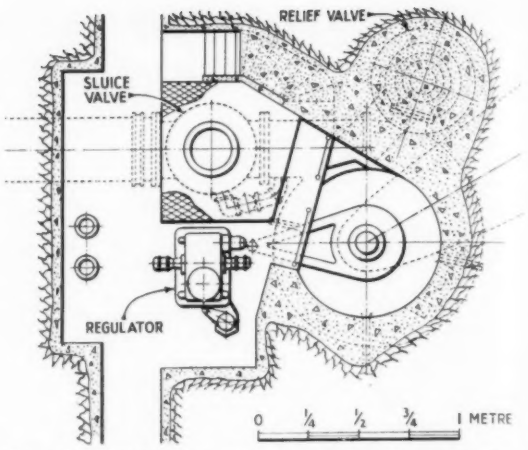


Fig. 18. Sketch plan of one of the Kvaerner-Brug turbines, showing disposition of regulator, sluice valve and relief valve

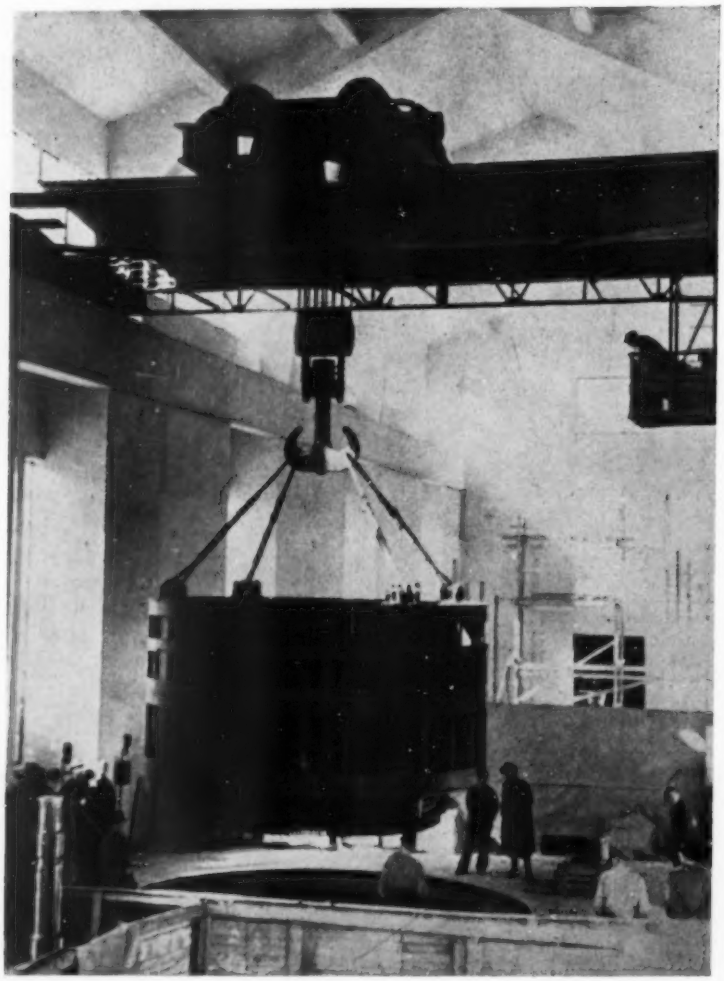


Fig. 19. Stator of one of the NEBB generators being lowered into position

The two Votna turbines were running very quietly when we inspected them, and we understand that there is no trouble from vibration or cavitation at any load. There is nothing unconventional in the design adopted to deal with the required head, the machines following Kvaerner Brug's normal practice with special attention to such matters as gland design and mechanical strength. The spiral casings are of cast steel, weighing 40 tons, and have been made in four pieces. The runners, each of which weighs 13 tons, have a diameter of 2,400 mm. and have steel-plate vanes cast into a cast-steel boss and ring. All parts of the guide apparatus that are immersed in water are either of stainless steel or are stainless-steel lined; stainless-steel lining is also applied to the most vulnerable parts of the runner.

Leakage water collecting in the turbine cover is withdrawn by ejectors when the turbine is stationary but is removed centrifugally when the machine is running.

The design of the regulator ring is exceptional, as this unit consists of a steel casting with a long cantilever arm cast intregral with the ring, so that the servomotor acts with an exceptionally high leverage (see Fig. 18).

Servomotor and governor gear are incorporated in one unit, and governor oil is supplied at 12-15

kg. per sq. cm. by an a.c. motor-driven oil pump with a d.c. motor-driven pump as standby. The governor is belt driven from the turbine shaft, the arrangement, of course, being safeguarded by a spring-controlled jockey pulley provided with an electric contact, which shuts down the turbine in the event of belt breakage.

To prevent an excessive pressure rise in the event of a sudden shutdown, a relief valve leading to a diffuser is fitted in a branch in the turbine casing, and operates in conjunction with the governor servomotor. According to tests that have been carried out, the speed of the generating set on a complete shutdown rises 19 per cent. and the water pressure rises 8 per cent. over the static value. The guide vanes are closed in 2·3 seconds, and the relief valve requires 24 seconds for opening and reclosing.

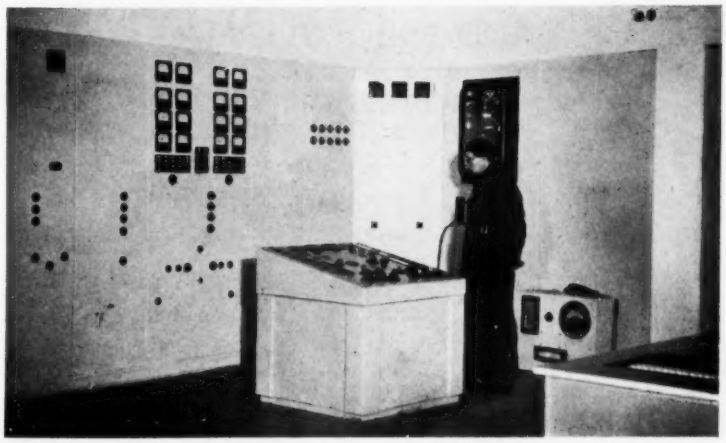


Fig. 20. A corner of Ruud station control room. When the Hol machines are installed the control desk will be extended

In advance of each turbine is a Kvaerner Brug sluice valve weighing 35 tons and having an inside diameter of 1,300 mm.

The turbines for the third and fourth units will be physically almost identical with those already described, but they have been designed to work on the somewhat lower head from Urunda; they will have an output of 67,000 h.p. and their specific speed will be 85 metric units as against 74 for the Votna machines.

Alternators

When the rating of the Votna turbines was increased from 60,000 to 65,000 h.p. this naturally involved rerating the alternators, but fortunately the makers, A/S Norsk Elektrisk & Brown Boveri, were able to guarantee their machines for a full-load rating of 50 MVA as against the original figure of 45 MVA.

The stators are of fabricated construction, the laminated cores having an inside diameter of 3·3 m. and a length of 1·8 m. Roebel-type conductors are used, giving two conductors per slot and connected in two parallel groups, the generating voltage being 9·35 kV.

The rotor spiders consist of cast-steel rings shrunk on to core-drilled forged-steel shafts, the poles being secured to the spiders by double dovetails.

The thrust bearing in each case is carried on a bracket mounted on the top of the stator, which thus carries the full thrust load. It is of the Michell type and runs in an oil chamber containing a nest of water-cooling coils. An upper guide bearing is carried on the bracket immediately below the thrust, and a lower guide bearing is carried on a second bracket below the machine. Both guide bearings are lubricated by an a.c. motor-driven pump, with a d.c. motor-driven pump as standby. In the machines now being built for the third and fourth units the guide bearings will be self-lubricating.

On the lower guide-bearing bracket are mounted the brakes, which are somewhat unusual in that instead of rising vertically to come into engagement they move horizontally with a caliper action to engage the inner and outer surfaces of a steel ring bolted to the bottom of the rotor spider.

Main and pilot exciters are coupled to the alternator shaft above the thrust bearing.

Ventilation is not on the usual closed-circuit system, but cooling air is withdrawn from outside the station by a duct communicating with the alternator chambers and returned through a second duct. There is no objection to such a course as the air at Hol is clean, and the expense of water coolers is avoided. CO_2 fire protection is installed, operation of which automatically shuts off the chamber of the machine affected from the supply and return ducts.

Two house sets are installed for driving station auxiliaries and for supplying the staff houses, consisting of Kvaerner Brug horizontal Pelton turbines direct coupled to NEBB alternators, each rated at 600 kW at 220 V. Normally one machine acts as standby.

Electrical System

A single-line diagram of the electrical system is given in Fig. 21. To minimise the short-circuit current on the 9 kV side a somewhat unusual transformer arrangement has been adopted. Both main generators are connected to a single transformer bank consisting of three single-phase units, but each of these units has two electrically separate primary windings, one for each generator, and a common secondary. The primary windings are arranged concentrically round the secondary to obtain a low reactance and improve stability. The three primaries for each generator are connected in delta, and the secondaries are in star, giving a secondary voltage of 220 kV, the secondary neutral point being earthed through a Petersen coil.

The transformer units, which were supplied by A/S National Industri, Drammen, are naturally cooled to about two-thirds load, after which the cooling is supplemented by fans. The Petersen unit was built by A/S Per Kure, Oslo.

Synchronising, which can be either manual or automatic, is carried out on the low-tension side, each generator being connected directly to a 4,000 A 650 MVA NEBB air-blast circuit breaker. These breakers are housed in the station, and bare conductors lead

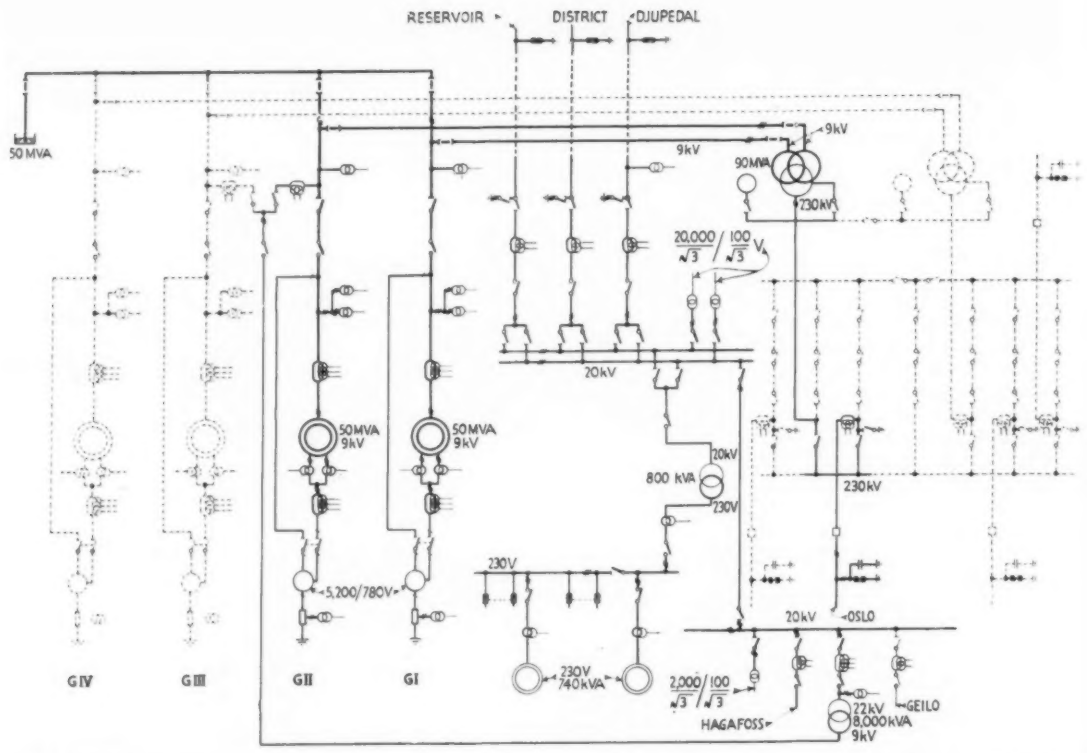


Fig. 21. Single-line circuit diagram of Ruud station and transmission system. Future extensions are shown dotted

therefrom to the transformer bays, which form one side of an outdoor switchyard adjacent to the power station. In this switchyard a 5,000 MVA Brown-Boveri air-blast circuit breaker controls the supply to a 220 kV transmission line to Oslo, of which we shall speak in more detail later.

Compressed air for the high and low-voltage air-blast circuit breakers and other apparatus is supplied by two two-stage air compressors, one acting as stand-by, producing air at 30-35 kg. per sq. cm., which is reduced to about 15 kg. per sq. cm. for normal operation. Compressed air is also used to insulate the 9 kV voltage transformers. The current transformers are of the bushing type without oil. All the 9 kV equipment is insulated for a nominal voltage of 20 kV.

For test purposes either generator can be coupled on the 9 kV side to a 45 MW water resistance.

When the third and fourth generating sets are installed they will be connected to a second transformer bank arranged in precisely the same manner as that already installed, and the switchyard will be completed to serve a second 220 kV line to Oslo. Two other lines will also be constructed to Aurland. To afford the requisite control the switchyard will be arranged with main and auxiliary busbars. Eventually three Hol-Oslo transmission lines will be needed, and it is then proposed to raise the voltage from 220 kV with isolated neutral to 300 kV with solidly earthed neutral.

An earthing bus system has been installed in and around the switchyard consisting of a network of copper strand buried about 18 in. deep. All outdoor and indoor equipment is connected to this earthing system, which has a resistance of about one ohm.

Power for construction sites and for general supply

(Continued on page 428)

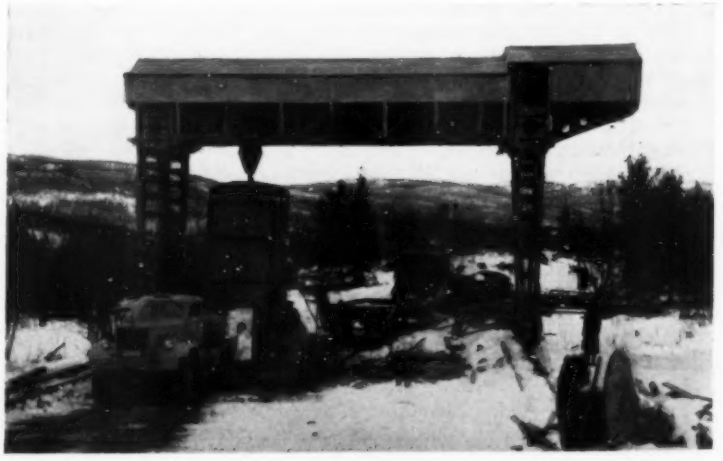


Fig. 22. One of the National Industri transformer units arriving on site

The UNIPEDE Conference

We present a summary of the papers given at the Hydraulics Session of the recent Conference of the International Union of Producers and Distributors of Electricity.*

THE International Union of Producers and Distributors of Electrical Energy, known universally as UNIPEDE from the initials of its French title, was founded in Paris in 1925, and it is, of course, an international association of organisations which, in each participating country, primarily represent the interests of the public-electricity-supply industry. Thus it does not include Government Departments, industrial concerns who generate their own electrical energy, or manufacturers of electrical plant.

The Conference is held every three years, and the 1955 meeting took place in London from September 19 to 23. The formal meetings at which many papers were presented were followed by study tours including visits to the hydro-electric installations in the North of Scotland and North Wales.

The hydro-electric section included seven papers, and the session at which they were discussed was held under the presidency of Direktor Carl Kromer, of Badenwerk A. G., while the Chairman of the hydro-electric generation study committee was Dr. Claudio Marcello, Director of Construction of the Edison Company, of Milan.

The first paper took the form of a general report by Mr. Charles Aeschimann, President of the Aar and Tessin Electricity Supply Company, of Olten, in Switzerland. Mr. Aeschimann said that the progressive exhaustion of the hydro-electric resources of a region gave rise to major problems. It became necessary to develop the waterfalls still available in such a way that the whole of the hydraulic power might be utilised at as small a cost as possible, not only in the intermediate future, but also on a long-term basis. He went on to study this question from the Swiss point of view. The results of his investigations led him to the belief that it was necessary that there should be a modification of present-day tendencies towards decreasing seasonal storage to the advantage of increasing the power generated in summer. In addition, he thought it would appear opportune to equip storage stations with higher-rated plant, and above all to create daily compensation reservoirs whenever possible in order to take into account the probable "sharpening" of the load curve. Mr. Aeschimann suggested that energy transfers with neighbouring countries would continue to play a definite role, but that opinions were divided on the subject of any great development of these transfers.

In order to illustrate possible developments, Mr. Aeschimann analysed the structures of the load curves for working days in winter and in summer at a time when the consumption will be approximately three times that existing at present. He thought that run-of-river plants might reasonably be considered as occupying the base part of the diagram, storage plant would deal with the peaks, with thermal plant carrying the load between these two portions.

The paper went on to give an appreciation of the situation appertaining in countries bordering on Switzerland. It appeared that the same viewpoint obtained in France and Italy, where the problem of meeting the peak load is predominant. It was found that the utilisation of hydro-electric stations in France had been improved by constructing storage reservoirs and by bringing both new gas-turbine generating units and old steam plant into service in association with the hydro-electric schemes. In Italy it was seen that power generation using natural gas as a fuel had progressed rapidly and was now beginning to take over the base of the load curve, hydro-electric power supplying the peaks. The author showed that Austria possessed large, unexploited water-power resources, thus allowing for the sale of energy at low cost in the form of power transfers to neighbouring countries. In regard to Western Germany, it was shown that hydro-electric generation was relatively low in relation to the total power, and could be completely absorbed by the existing demands within the country. The load on the thermal stations was to some extent evened out by means of storage operation, pumping, and international power transfers.

Mr. Aeschimann's conclusions are quoted verbatim. "We see that Germany offers extensive possibilities for absorbing surplus hydro-electric energy, generated by other European countries, for partial regularisation or in exchange for energy of a different character. Thanks to its large thermal reserves Germany may envisage absorbing high-grade energy to return the corresponding amount of low-grade energy, or vice versa.

"On the other hand it has been seen that France, Italy and Switzerland will not have hydro-electric resources to harness for much longer. Is it preferable for these countries to organise themselves in order to produce energy in the grade which will be the most useful to their load curves, or should it be that they should use streams and storage sites to the best advantage, without considering the balancing of their own requirements for energy of various grades, which will be supplied by very extensive international energy transfers? At first sight the second solution appears to be in better agreement with optimum economy. However, it is possible that the power transmission costs and losses will more than offset the theoretical gain achieved. On the other hand, the supplying of energy is a requirement so vital that each nation has an understandable tendency to depend as little as possible on foreign countries at critical times.

"The opinions that we in Switzerland have had

* [It should be stressed that the majority of communications to UNIPEDE related only to European practice, and thus we venture to warn the reader against drawing conclusions applicable to worldwide hydro-electric affairs from the abstracts of the papers we are presenting in this issue. This, of course, in no way detracts from the value of the papers regarded in their proper context.—EDITOR, WATER POWER.]

communicated to us show some slight variation of thought on the subject of this important problem."

The next report took the form of a summary by Dr. Ing. Carlo Semenza, Direttore Della Società Adriatica di Elettricita, Venice. His subject was the "Evolution of River Development Schemes in Relation to Recent Progress in Underground Construction Methods: The technical and economic possibilities of locating pressure-reducing stations immediately below large dams to reduce the pressure in headrace tunnels." The report summarised three papers; two on the subject indicated by the first part of the title of the report, and presented by Monsieur H. Lüthi, Chief Engineer, S.A. des Forces Motrices de la Maggia, Locarno, and Monsieur Rousselier, Vice-Director of Equipment, Electricité de France, while the second subject indicated in the title had been dealt with by a paper by Signor G. Gentile of the Società Indrolettrica Piemonte of Turin.

In dealing with M. Lüthi's paper, Dr. Semenza said that the Val Maggia scheme in the Tessin in Switzerland was one in which the penstocks and the power station were situated below ground. This arrangement had been chosen because of its lower cost when compared with that of locating the corresponding structures on the surface. Military considerations and the desire to preserve amenities, as well as other reasons not related to the economics of the scheme were, it was stated, not allowed to affect the final decision. The geology of the site was particularly favourable, but the scheme became suitable for development only after it had been proved that it was possible to construct two long tunnels within a comparatively short time, as a result of modern technical progress which lowered the excavation costs.

Among the features of special technical interest in this scheme was the fact that the slope of the shafts at Verbano had had to be arranged so that their axes were perpendicular to the strata. Another feature was the exceptionally long distance (970 yards) between adits on the pressure shaft at Cavergno. Special measures of considerable technical interest had been taken to perfect the ventilation, illumination and soundproofing in this power station.

Monsieur Rousselier's paper, said Dr. Semenza, was of special value because it emphasised the really outstanding advances in tunnel construction methods which had taken place in recent years, thus providing designers with much greater freedom in the overall planning of a scheme. The particular advances on which Monsieur Rousselier commented could be classified as: much better initial information on site characteristics; greater speed of drilling and excavation in tunnelling practice and a high degree of mechanisation; progress in tunnel lining, for example, the use of concrete lining applied by mechanised methods and progress in the use of steel for tunnel linings; and advances in the technique of excavating the large machinery halls for underground power stations.

Signor Gentile discussed the problem of supplying a hydro-electric station from a reservoir with a large usable variation in level. He said there were three ways of dealing with this problem. First, the water from the reservoir could be spilled into the head pond of the station, dissipating the energy corresponding to the changes in reservoir level. Secondly, a two-stage scheme could be employed in which the reservoir was connected through a short penstock to a first station arranged near the reservoir itself, which in turn would discharge into the intake pond of the second station, which would usually be the main plant, located farther downstream. Thirdly, a single-stage scheme could be employed, with a penstock connecting the reservoir directly to the power station, which again could be located at a considerable distance from the reservoir. Dr. Semenza said that Signor Gentile had given exhaustive consideration to the second and third methods, from both economic and technical points of view. He felt that the third solution had obvious advantages, although not free from difficulty.

In the concluding part of Dr. Semenza's paper he gave some interesting figures on tunnelling costs in Italy, and the striking reduction in man-hours per metre is shown in the following table:

Scheme	Years of Construct'n	Diameter in metres	Manhours per metre
Cencenighe ..	1938/9	2·70	275
Boite	1950/1	2·80	210
Maé	1953/4	2·75	170

The conclusions finally reached by Dr. Semenza after summarising the three papers mentioned above, and adding much new material of his own, were that advances in underground construction methods had definitely led to a greater freedom for the designer, who was nowadays rendered independent of orography and topography, and who could now include in his scheme structures of dimensions which would have been excluded previously in view of the long construction period then required. In addition, he found "a certain reduction in the rising costs of development schemes caused by the general economic law which derives from the fact that, with some exceptions, the schemes still to be constructed show a smaller profit margin than those completed in the distant or the more recent past."

The next paper in the hydro-electric section came from Monsieur George Bardon, of the Directorate of Generation and Transmission of Electricité de France. It dealt with the nature and method of operation of steam-power stations used for equalising water power. Monsieur Bardon, as in the case of previous speakers mentioned above, stressed the fact that water-power resources were becoming used up. He dwelt at some length on the technical conditions with which thermal power stations in those countries now compelled to consider their inception to assist the hydro stations had to comply. These conditions, he said, were very specialised. The majority of the data given in the paper related particularly to the flexibility of steam plant and are therefore not of specific interest to the hydro-electric engineer. The conclusion reached by Monsieur Bardon, however, after the examination of a number of other papers given as an appendix to his main thesis, was that much greater attention would now have to be given to the design of steam plant for this specific duty.

Dr. Marcello, in his paper on "Evolution in Dam Construction and its Effects on the Cost and Quality of the Energy," first surveyed the essential data of a number of European dams. He stated that this survey revealed that the savings derived from technical progress consisted not only in a lower cost of energy but more particularly in an extended field of constructional activity to more difficult situations, as well as in

a greater value of peak power supply. Dr. Marcello said that it appeared now to be true that reservoirs of small storage could justify unit costs related to stored kWh which were substantially higher than those for larger reservoirs. This fact depended on the specific function of a small reservoir, mainly to ensure an availability of power in the peak-load periods rather than a steady output during long drought periods, and also because the small reservoir refills and drains itself several times in a year, and thus turns over a volume of water considerably greater than its capacity. He ended by saying that the future evolution of all hydro-electric development would most probably confirm and lay stress on the trend towards ensuring an ever more valuable peak power service, since the general production of current would be undertaken by other sources of energy, which, in the meantime, technical progress would have made more economically available.

The interesting subject of forecasting of run-off and hydraulic producibility was dealt with by Monsieur S. Ferry of Electricité de France. He showed that the forecasting of river flow in France due to melting snow had been greatly improved in both the Alps and the Pyrenees, and its accuracy could now be checked statistically. A vast amount of work had been carried out by the Electricité de France engineers in the field, and this work was extended in 1953 to the preparation of forecasts for the total producibility in these two regions. The method of sounding snow depth had been improved, mainly by increasing the core diameter from 45 to 54 mm. and removing external projections on the portable probe, which could be divided into 80 cm. lengths, while in addition solid probes of 1·5 and 2·5 m. in length and 70 mm. outside diameter were now being used at permanent locations for periodic soundings at medium altitude.

A German paper dealt with the economic value of small reservoirs, taking into account the type of load curve and the part played by thermal generation. It was prepared by Dipl.-Ing. Werner Pietzsch of Bayerische Wasserkraftwerke A.G., München. Herr Pietzsch dealt with the exploitation of hydraulic power from rivers with a view to adapting the production of electrical energy, in accordance with its daily characteristics, to the load curve. He said that the harnessing of the river must be carried out in stages, so as to hold up the flow of water for a time in a series of small reservoirs and thus increase the quantity of water available at peak load periods, so that more energy could then be produced. The author investigated the hydraulic phenomena related to this type of exploitation, and endeavoured to determine the losses which would occur if the stages at which the stations were situated were not continuous, that is to say if there were sections where uncontrolled flow was permitted. He pointed to the practicability of producing power for peak loads by demonstrating the example of a hydraulic system comprising 26 power stations in stages, ten of which had already been built. Herr Pietzsch said that the object of the report was to call attention to a type of exploitation which fitted in with existing conditions, and which he felt had not so far been adequately employed because partial solutions only had been tried, without taking into account the overall conditions in the river.

The final report came also from Electricité de France, and was presented by Monsieur Marcel Mary, Directeur de la Region d'Equipement Hydraulique, Massif Central 1, who dealt with new developments in low-head power-station projects. He described these developments under various headings, the first being the use of the buttress or pillar station layout, whereby instead of grouping all the sets into one building situated at one end of the dam, they were placed in the buttresses of the spillways. The machines used were of the outdoor or semi-outdoor types, and a travelling crane was provided over the station plant, which might also be used to raise the flood-gates and for the operation of screens and sluice gates. In some cases this layout might lead to a reduction in the overall length of the installation, and in other ways considerable savings might also be effected.

Secondly, Monsieur Mary dealt with the elimination of spiral intakes in vertical-shaft turbines. He said it was quite easy to obtain an even distribution of the water on the wheel, simply by placing a few concrete profiles at the intake, together with fixed directing elements. The wheel would then be provided with adjustable blades, and isolating gates should be provided for safety at the outlet of the venturi. Monsieur Mary said that such a layout blended well with the shape of a pillar-station installation.

He next discussed the utilisation of horizontal-shaft turbines with axial flow. In this type of layout the installation included a tube with a varying cross-section in which an impeller was placed. Several methods might be considered for regulating the flow, including the use of a propeller wheel with adjustable guide vanes, and a Kaplan wheel with fixed or adjustable vanes. The use of submerged (bulb) alternators was also mentioned in the paper. This type of plant consisted of a closed metallic shell in the stream of water diverted for the turbine, inside which was placed the alternator. The heat dissipated by the machine was transmitted to the wall of the shell by the fluid surrounding the machine. This fluid might be oil, air at atmospheric pressure, compressed air, or hydrogen.

Monsieur Mary ended by considering the use of overdrive gears, since low-head turbines ran slowly, causing the alternator to be relatively large. In employing some of the solutions to low-head problems mentioned earlier, it was particularly advantageous to be able to reduce the size of the machine, in order to reduce the width of the section of the station or of the pillar, on the one hand, and to disturb the stream of water as little as possible on the other.

Spherical Valves. The Dominion Engineering Co. Ltd. of Canada have issued a new bulletin (No. 214-20) which describes and illustrates the range of spherical valves they now manufacture. This firm has now entered into an agreement with Neyrpic, the well-known French manufacturers, for a complete exchange of knowledge concerning spherical valves so that any improvements devised by the one company will be adopted by the other.

"ELIN" Electrical Products. A folding brochure issued by this well-known Austrian firm calls attention to the extensive range of equipment which it now produces. This includes generators of all kinds, transformers, motors, rectifiers, switchgear, control rooms, automatic arc welding machines, etc., and the firm is also prepared to undertake the design and construction of complete power plants, including the sub-stations and high-tension transmission lines.

The Role of Evaporation in Water-Power Studies

The author of this article shows how, in a multiple-purpose project, it is possible by proper design to circumvent excessive evaporation chargeable to the inclusion of power

By GEORGE A. WHETSTONE, Ph.D.,
Professor of Civil Engineering, Texas Technological College.

POWER generation is usually considered to be a non-consumptive use of water. In fact, it is this circumstance which makes combinations of power development with municipal, industrial, or agricultural water supplies so attractive. A detailed audit of the water balance of a multiple-purpose project may, however, reveal that a major portion of the total evapo-transpiration is properly chargeable to the power operation. It is thus frequently desirable to modify traditional designs and operation schedules of reservoirs in order to retain the economic benefit of power support, while suffering the minimum possible loss of water because of it.

Since the power developable is proportional to the head, a given amount of water will produce more power from a reservoir with a large surface and flaring sides than from one with vertical walls. Some idea of the numerical ratios of power producible and of evapo-transpiration losses may be gained by considering the mathematically tractable idealised reservoirs of Table I.

The total volume and the depth of each of the reservoirs being the same, we see from line 6 of the table that the ratio of the energy available in a n-cone to that available in a cylinder is $(2n + 1)/(n + 1)$ for a tailrace at $z=0$. Actually, the advantage of the cones would be greater than this since the efficiency would drop off with low heads and thus more water would be used at low efficiency in the cylinder than in the cones.

In this idealisation of the situation which occurs at dams with power houses at approximately river-bed level it would be more realistic to assume that the drawdown was only from elevation H to elevation $H/2$. The ratios of water withdrawn in this case (line 3) would be $2 - (1/2)^{2n}$. The ratios of total energy content at constant equal efficiencies (line 7) would be

$$\frac{4}{3}\left(\frac{2n+1}{n+1}\right)\left[1 - (\tfrac{1}{2})^{2n+2}\right]$$

Thus the relative effectiveness of a cubic foot of water in the upper half of the two reservoirs would be

$$\frac{2n+1}{3(n+1)}\left[\frac{2^{2n+2}-1}{2^{2n+1}-1}\right]$$

For the same total volume of water through the power house, however, a more substantial advantage lies with the n-cone. The energy ratio in this case (line 8) would be

$$\frac{4}{3}\left(\frac{2n+1}{n+1}\right)\left[1 - (\tfrac{1}{2})^{(2n+1)(2n+2)}\right]$$

For a power plant at an elevation other than $z=0$, the ratios derived above would not be valid. Since, however, the differences in potential energy of two units of water (of W pounds each) at elevations h_1 and h_2 above the power house are $\eta W(h_1 - h_2)$, it may be seen that the same absolute advantage in additional kilowatt-hours would accrue to a conical reservoir in all cases.

Evaporation, however, is affected more directly by area than by volume; it is a fair approximation to state that the same depth of water would be lost off each of the reservoirs by evaporation from the free water surfaces. In addition to this, the cones, especially those for large values of n, would have extensive areas of shoals which provide ideal habitat for salt cedars, tamarisks, and other water-loving plants. These might well continue to transpire ground water at a rate approximately that of open surface evaporation even after a large surface reduction due to a minor decrease in depth[1]. With this hypothesis, the ratio of evapo-transpiration losses (line 9) would be $2n + 1$.

The practical significance of these figures depends on the availability of water and on the evaporation rate at the reservoir. If spillway flow is frequent, a large surface is desirable; in a desert setting it can be catastrophic.

When power is generated in a "run-of-river" plant none of the evaporation losses are properly chargeable to the operation as such. With daily pondage, the largest reservoir surfaces are exposed at night when evaporation is least. Here, however, moist banks and vegetation may waste large volumes of water in a season. As was stated in connection with the mathematical reservoirs, a rough estimate of the loss may be obtained by multiplying the maximum pond surface by the depth of free water evaporation in a given period of time. A further additional loss occurs in the tailrace where greater areas receive a periodic wetting due to concentrated releases than would be affected under steady flow regimes.

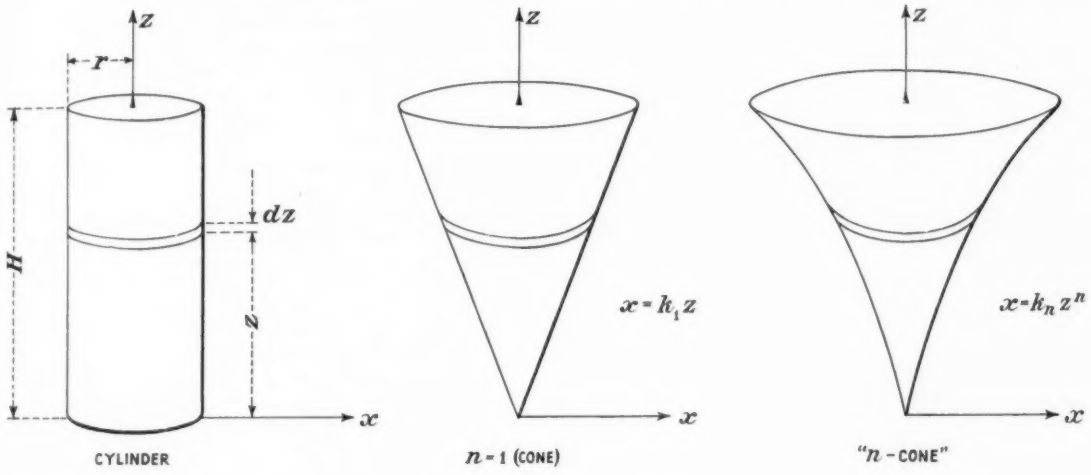
Reservoirs with seasonal storage, especially those in arid or semi-arid regions, usually have large sur-

faces. Frequently extensive areas of shoal water result from the natural topography of the flooded valley and from the deposits of sediments which accumulate at the heads of the reservoirs. These mud banks and the adjacent shores, their water tables raised by underflow from the reservoirs, may develop dense stands of vegetation. The losses inherent in this situation may properly be debited against the power account only in so far as the site was selected to obtain a large head of water (comparable to choosing a large value of n in the idealised problem) or in so far as provision was made for a "power pool" of water beyond that held for all conservation purposes. Even here, the accounting becomes complicated if the water in the power pool must be released subject to certain requirements of downstream water rights. Moreover, one may not become righteously indignant over water evaporating from a power pool if it would otherwise have formed part of a flood wasting into tide water.

Usually it is economically unsound to construct a seasonal storage reservoir without including a power plant; it seems even less reasonable to permit the plant to stand idle under a head of water during the off-season. And it need not, for by properly locating a second dam one may have power and water both when each is wanted[2].

The second reservoir, however, adds to the exposed water and vegetation surfaces and may incur large increments in evapo-transpiration losses. A study of the Elephant Butte-Caballo system on the Rio Grande in New Mexico[3] has indicated that the addition of Caballo dam some 20 miles below Elephant Butte

TABLE I. MATHEMATICAL CHARACTERISTICS OF IDENTICAL RESERVOIRS



LINE	ITEM	CYLINDER	CONE AND "n-CONE"
1	d (VOLUME)	$\pi r^2 dz$	$\pi k_n^2 z^{2n} dz$
2	TOTAL VOLUME	$\pi r^2 H$	$\pi k_n^2 \frac{H^{2n+1}}{2n+1}$
3	VOLUME ABOVE $Z = \frac{H}{2}$	$\frac{\pi r^2 H}{2}$	$\pi r^2 H\left[1-\left(\frac{1}{2}\right)^{2n+1}\right]$ *
4	ELEVATION OF MID-VOLUME	$\frac{H}{2}$	$H\left[1-\left(\frac{1}{2}\right)^{2n+1}\right]$
5	POTENTIAL ENERGY OF THE ELEMENT (WITH RESPECT TO $Z=0$)	$\eta\pi\omega r^2 z\, dz$	$\eta\pi\omega k_n^2 z^{2n+1} dz$
6	TOTAL POTENTIAL ENERGY (WITH RESPECT TO $Z=0$) ASSUMING η CONSTANT	$\frac{1}{2}\eta\pi\omega r^2 H^2$	$\left(\frac{2n+1}{2n+2}\right)\eta\pi\omega r^2 H^2$ *
7	POTENTIAL ENERGY ABOVE $Z=\frac{H}{2}$ (WITH RESPECT TO $Z=0$), η CONSTANT	$\frac{3}{8}\eta\pi\omega r^2 H^2$	$\eta\pi\omega r^2 H^2\left(\frac{2n+1}{2n+2}\right)\left[1-\left(\frac{1}{2}\right)^{2n+2}\right]$ *
8	POTENTIAL ENERGY IN TOP HALF OF VOLUME (WITH RESPECT TO $Z=0$), η CONSTANT	$\frac{3}{8}\eta\pi\omega r^2 H^2$	$\eta\pi\omega r^2 H^2\left(\frac{2n+1}{2n+2}\right)\left[1-\left(\frac{1}{2}\right)^{(2n+1)(2n+2)}\right]$ *
9	SURFACE AREA	πr^2	$(2n+1)\pi r^2$ *

* FOR EQUAL TOTAL VOLUMES AND EQUAL H; i.e. $kn = \frac{r}{H^n}\sqrt{2n+1}$

Dam, in creating a reservoir with an average annual storage, from 1943 to 1950, of 122,400 acre ft., had introduced an average loss in evaporation minus precipitation of about 42,600 acre ft. Since some loss would have occurred from the reservoir area without the dam and since the loss from the smaller Elephant Butte reservoir is less than it would have been, a conservative estimate of the additional losses due to two-reservoir operation is about 20,000 acre ft. per year. The 160,000 acre ft. wasted in the eight years could all have been stored in Elephant Butte reservoir without causing spillway flow.

The solution suggested in the Rio Grande study—employment of a much smaller reregulating reservoir with provision for pumped-storage operation—should be considered in any similar situation. There are several advantages to such a solution in addition to the obvious one of water salvage through decreased evaporation. These include the following:

(1) The operation of the turbines through a narrower range of heads during the off-season is reflected in better efficiency.

(2) Valley land below a dam on a large river is apt to be the most valuable land in an arid area: it is the easiest to reach by gravity irrigation, it is adjacent to the natural routes of commerce, and it is usually fertile. Moreover, the ownership pattern is often complex with homes, churches, cemeteries and other holdings which should not be disturbed for insufficient causes.

(3) The addition of excessive area in a reservoir system, in increasing the evaporation, leads to degradation of water quality through concentration of salts. Since rivers in arid areas frequently have high chemical contamination from irrigation return water, as well as from natural causes, avoidable increases in salts should be shunned.

(4) Frequently such reservoirs are the only sources of water for a hydro-plant in an existing all-thermal network. Thus the storage volume desirable for optimum peaking operation might dictate far too large and expensive a reregulating reservoir if it were required to hold a season's releases, whereas the volume which would be sufficient if pumping were to be employed would be moderate.

Following the reasoning of item (4) it might often be more advantageous to construct a second reservoir on some dominating elevation near the shore than to employ a reregulating reservoir in the streambed below the main dam. In case an acceptable site were to exist at a height of n times the effective head obtainable between water surfaces at the main dam, the volume of water handled need be only in the ratio of 1 to n. Moreover, the possibility of securing a deep reservoir with steep walls and reduced surface area is much greater on uplands near a large valley than in the valley itself.

Such a pumped-storage power plant would normally be separate from the power plant at the main dam since the reservoir site selected might well be at a considerable distance from the dam and since the turbine or pump-turbine for the high-head duty would not be well adapted to service on the low or moderate heads at the main dam. While this would increase the expense somewhat, this might well be more than compensated for by the additional security of independent installations and by the fact that the pumped-storage plant would be available for peak loads all the year, leaving an intermediate belt on the load curve—and consequently a smoother stream flow below the dam—to the power plant at the main dam. The exact load distribution for a given water release would, of course, depend on the sizes of the pumped-storage plant, the main-dam plant, and the thermal equipment in the power network.

REFERENCES

[1] "Hydrology Handbook," American Society of Civil Engineers, 1949. Pages 129, 140.

[2] cf. "Reregulating Reservoirs for Multiple-Purpose Projects" by George A. Whetstone. WATER POWER, January 1955, pp. 26—28.

[3] Discussion of Robert L. Lowry's "Consumptive Use of Water. Special Case in Rio Grande Basin" by Isom H. Hale and George A. Whetstone. *Trans. Amer. Soc. of Civil Engrs.*, Vol. 117, pp. 1021—1022 (1952).

Yugoslavian Contracts. Holman Bros. Ltd., Camborne, England, have recently contracted to supply civil engineering equipment worth £34,000 to the Konstruktor and Kokin-Brod organisations in Yugoslavia. Both concerns will use Holman equipment in the construction of hydro-electric dams and tunnels. The Konstruktor concern is operating on behalf of the hydro-electric department of the Croatian Republic, at Vlasinaw. The Kokin-Brod scheme is in Serbia, on the Uratz river. Equipment includes over 100 rock drills, compressors, rippers and air-winches.

Aluminium Limited Expansion in Jamaica. An immediate expansion programme to more than double existing capacity of alumina production in Jamaica has been announced by Nathaniel V. Davis, President of Aluminium Limited, Montreal. "The additional alumina requirements for the Kitimat aluminium smelter in Canada and other world markets," Mr. Davis said, "will be met in part by this further expansion of company facilities in Jamaica."

When the expansion programmes are completed the capacity of Alumina Jamaica Limited will be increased to 543,000 tons of alumina per year. The present capacity is 230,000 tons and in March of this year the Company announced the start of construction to enlarge alumina capacity by 70,000 tons at an estimated cost of $11,000,000.

A. M. Byers Company. A yardstick for measuring basic cost factors in the installation of piping systems is contained in a new eight-page illustrated booklet just published by A. M. Byers Company, Pittsburgh.

The new publication, entitled "True Piping Economy," compares wrought iron and other types of pipe in terms of the three factors: initial purchase cost, cost of installation and cost of maintenance. Several case histories of piping installations are given and a digest of the important uses for wrought iron pipe in different types of industrial and municipal services is also included.

The David Brown Companies. A specimen copy of a new publication entitled "Exempli Gratia" has been sent to us by the David Brown organisation. It gives a clear picture of the organisation's manifold activities and interests, which now include gears of almost every description, machine tools, mechanical handling equipment, foundry work (including water-turbine castings), earth-moving equipment and tractors.

Reyrolle Protective Systems. Pamphlet No. 858 issued by A. Reyrolle & Co. Ltd. of Hebburn is essentially a reference list that has been prepared to act as a quick and handy guide to engineers responsible for the application of protective systems to networks and apparatus.

Design Features of the Flatiron Power and Pumping Plant

This paper* describes the design features of the generating units at the Flatiron Power and Pumping Plant of the Colorado-Big Thompson project. It includes a description of the 48,000-h.p. Francis-type turbines which operate under a maximum static head of 1,118 ft. and also a large 2-speed reversible pump-turbine motor-generator unit

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BUREAU OF RECLAMATION, U.S. DEPARTMENT OF INTERIOR.

THE Flatiron power and pumping plant is the largest and the terminal plant which utilises the power drop in the transmountain water-diversion system of the Colorado-Big Thompson Project. This completed project is a recent Bureau of Reclamation development which diverts water from the Colorado River on the western slope of the Continental Divide through the 13-mile-long Adams Tunnel to the eastern slope. It provides irrigation, hydro-electric power and other benefits for a large area northeast of Denver, Colorado. The profile diagram of the power-drop and irrigation features of the diverted water on the eastern slope is shown in Fig. 1. The design of this system is based on a water supply of 340,000 acre-ft., of which 310,000 acre-ft. are diverted from the western slope and 30,000 are obtained from the Big Thompson river. Water for the Flatiron power plant is supplied via the Flatiron penstocks and the Bald Mountain pressure tunnel from the Flatiron reservoir. This reservoir receives its discharge from the Pole Hill power plant. The afterbay of the Flatiron power plant supplies water to the Horsetooth feeder canal. Carter lake, which supplies water to the St. Vrain supply canal, is supplied from the Flatiron afterbay by the reversible pump-turbine in the Flatiron pumping plant. Provisions are also made for the generation of power at the pump-turbine when Carter lake water is released back through the plant to the Flatiron afterbay.

General Features

The Flatiron power and pumping plant structure is a semi-indoor installation. It consists of a reinforced-concrete structure which rests on siltstone, claystone, and sandstone. The roof is located high above the bed of the creek and is above any flash flood that is expected to occur in this locality. The main powerhouse crane of 100-ton capacity is mounted on the roof deck.

The combination plant contains two 48,000 h.p. Francis-type turbines and one reversible pump-turbine, motor-generator unit. The two main generating units have a combined hydraulic capacity of approximately 960 cusecs. and operate under a maximum static head of 1,118 ft. These units are designed to provide peak-load generation for the interconnected power system. The reversible pump-turbine unit has a rated pumping capacity of 370 cusecs. at a head of 240 ft. and is designed to supply Carter lake during off-peak hours. The unit may also be used for peak-load generation at any time.

Surge Tank

The Bald Mountain pressure tunnel conveys water from the Rattlesnake reservoir to the Flatiron penstocks. This 6,700-ft.-long tunnel is served by an inlet channel and trashrack structure in the reservoir and is provided with a 50 ft. diameter surge tank near the outlet portal of the tunnel. This simple, restricted-orifice type underground surge tank is designed to minimise the pressure surges induced by the sudden rejection of the flow at the turbines and to supplement the tunnel supply when the plant load is suddenly increased. It provides for contemplated fluctuations of 70 ft. between maximum downsurge and upsurge in the surge tank.

Penstocks

Two parallel, variable-diameter, 84-in., 78-in., and 72-in. welded and riveted, plate-steel penstocks are provided as waterways to carry water from the outlet of the Bald Mountain pressure tunnel to the main generating units in the Flatiron power plant. The penstocks are about 5,800 ft. in length and have a maximum shell thickness of $1\frac{5}{16}$ in. at lower end. For the upstream portion of each penstock comprising about 2,700 ft., an ASTM Designation A285 Grade C steel was used. For the remaining lower portion of each penstock a higher strength ASTM Designation A212 Grade B steel was used. All penstock sections fabricated from the A212 steel and from the A285 steel over 1 in. in thickness were thermally stress-relieved

*Contributed by the Hydraulic Division for presentation at the A.S.M.E. Diamond Jubilee Spring Meeting, Baltimore.

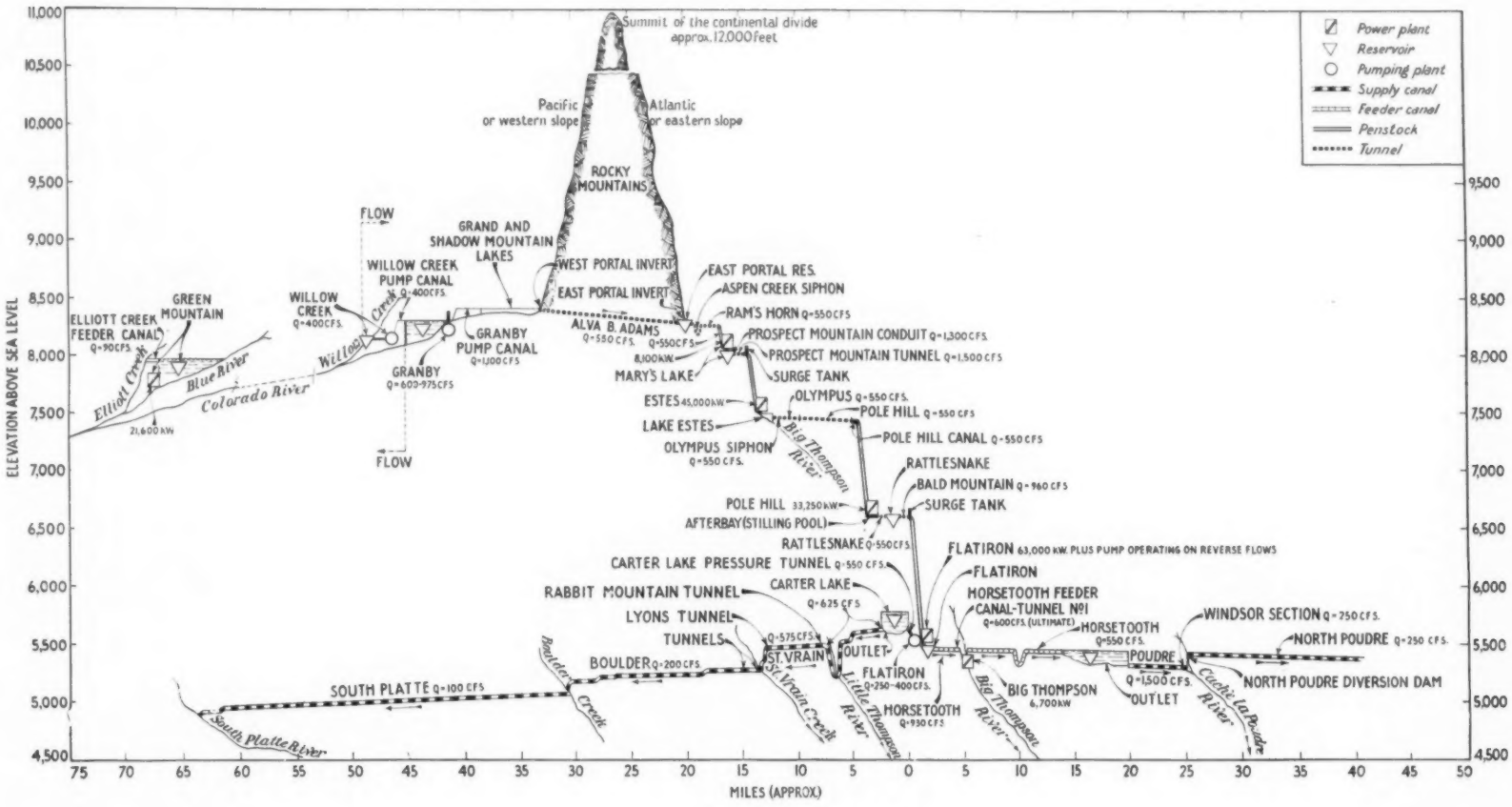


Fig. 1. Profile diagram of Colorado-Big Thompson project

after welding. Each individual erection section was then subjected to a hydrostatic pressure test in a specially designed pressure testing machine where a test pressure of 1½ times the design pressure was applied. The field girth joints which were made from A285 steel were butt welded and those made from A212 steel were butt riveted, except the downstream end sections which were Dresser-coupled. For the most part the penstocks were installed above the ground with supports consisting of double-ring girders welded to the pipe. The penstocks were fabricated and installed by the Southwest Welding and Manufacturing Company.

Turbines

The main turbine installation for the plant consists of two vertical-shaft, Francis-type, 514 revs. per min. turbines, each having a capacity of 48,000 h.p. at full gate opening when operating under an effective head of 1,055 ft. The general arrangement through one of these units is shown in Fig. 2. Each turbine spiral case, pressure regulator valve body, and other parts subject to penstock water pressure, are designed for 600 lb. per sq. in., which is the maximum pressure, including waterhammer, that can be obtained with the pressure regulator functioning. They were shop tested at 900 lb. per sq. in., field tested at 600 lb. per sq. in., and embedded in concrete while under an internal pressure of 450 lb. per sq. in.

Each turbine is designed and constructed so that all removable parts may be removed from above by means of the main powerhouse crane, and can pass through the circular pit below the generator and through the generator stator. Provision is made in the design to permit the turbine shaft and runner to be raised or lowered as a unit for purposes of checking or inspecting the generator thrust bearing or disconnecting the main shaft coupling.

A critical shortage of nickel existed during the period of construction of the Flatiron turbines and for this reason aluminium bronze was substituted in most of the parts where stainless steel was originally called for in the specifications. This substitution included the runners which are cast of "Ampco" aluminium bronze. However, a spare interchangeable carbon-steel runner was also provided. The turbines and pressure regulator valves were designed and furnished by the Pelton Water Wheel Company.

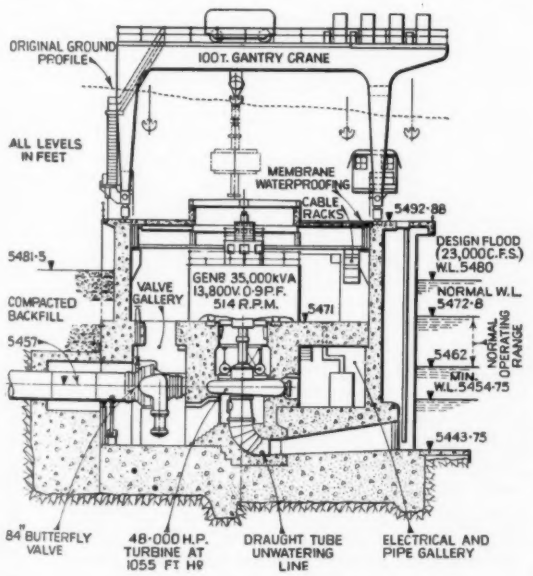


Fig. 2. Cross section through main generating unit

Pressure Regulators

A pressure regulator of the internal-needle type is installed at each turbine to reduce the pressure rise in the penstock due to the rapid closure of the turbine wicket gates and to provide a water bypass

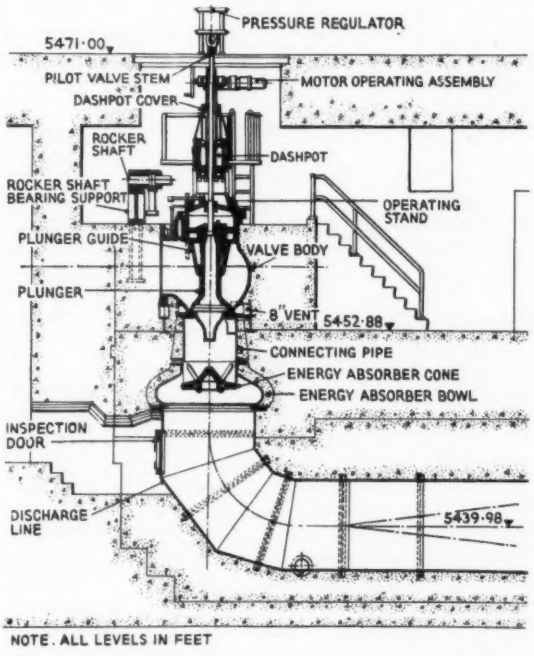


Fig. 3. Cross section through pressure regulator

during periods of shutdown. The water passage for the pressure regulator or relief valve for each unit is directly connected to the turbine spiral case and is designed to operate either as a synchronous bypass or as a water saving relief valve having a capacity equal to 100 per cent. of the flow capacity of the connected turbine. It is mechanically connected to the turbine wicket-gate mechanism and will stall the servomotor if the pressure regulator valve sticks or fails to open, thus ensuring a limitation on the water-hammer during rapid load rejections. The pressure regulator is normally set to operate as a water-saving relief valve which opens in step with the wicket-gate closure at rapid load rejection and then slowly recloses under the control of a dashpot. It does not open when the wicket gates slowly close during normal load changes. Each pressure regulator also can be operated as a continuous bypass when the turbine wicket gates are closed.

The energy of the jet leaving the pressure regulator-valve orifice is dissipated in the lower part of the pressure regulator shown in Fig. 3. The jet impinges on

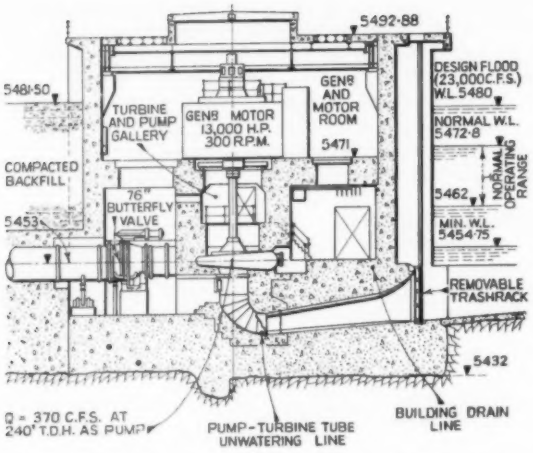


Fig. 4. Cross section through pump-turbine motor-generator unit

the steel energy-absorber cone and is doubled back on itself by a steel bowl surrounding the base of the cone. A steel-lined elbow draft tube conducts the flow to the tailrace.

Governors and Generators

The governors for regulating the speed of the turbines are of the oil-pressure, cabinet-actuator type, with electrically driven speed-responsive elements. The governor rating corresponding to the capacity of the turbine servomotors is 70,000 ft.-lb. The actuator main relay valves are adjusted to limit the rate of movement of the turbine gates between 5 and 15 sec. for a full gate opening or gate closing stroke. The governors were designed and furnished by the Woodward Governor Company.

The two main generators are 3-phase, 60-cycle, alternating-current generators with an output of 35,000 kVA each at the rated voltage of 13,800 V and at 90 per cent. power factor. Each generator has a self-aligning vertical equalising Kingsbury type thrust bearing and an upper guide bearing located above the rotor, and a lower guide bearing below the rotor. All parts of the generators and exciters are designed and constructed to withstand safely the stresses resulting from a runaway speed of 950 r.p.m. The generators were manufactured and installed by the Westinghouse Electric Corporation.

Pump Turbine

The pump turbine at the Flatiron power and pumping plant is of particular interest as it is one of the first large units of its type to be placed in service in the United States. The general arrangement through this unit is shown in Fig. 4. The pump rating is 370 cusecs. at 240 ft. total head. As a turbine-driven generator the unit is rated at 8,500 kVA. The combination unit is basically a pump with only 6 impeller vanes but it has fixed stay vanes like a turbine. It has no wicket gates or governor and therefore always operates as a turbine at "full gate." The butterfly valve adjacent to the unit is held in the wide open position when the unit is pumping or generating. Because of the dual type of operation, trashracks are provided at both headwater and tailwater. A 42-in. diameter submerged tube valve is installed in the conduit system to bypass the pump-turbine unit when the irrigation flow requirements exceed the water capacity of the unit as a turbine.

At this installation the head on the unit varies from 290 to 140 ft. for the turbine and 170 to 300 ft. for the pump. Model tests by the pump-turbine manufacturer for the particular impeller selected indicated that with these head ranges higher efficiencies were obtained by running the turbine at a lower speed than the pump. The adopted speeds were 300 revs. per min. when pumping and 257 when turbining.

The pump-turbine spiral case and other parts subject to penstock pressure are designed for 200 lb. per sq. in., which is the maximum pressure that can be obtained with the discharge valve closed and a runaway speed in the pumping direction of 340 revs. per min. The pump-turbine was designed and built by the Allis-Chalmers Manufacturing Company.

Motor Generator

The motor generator at the Flatiron power and pumping plant is designed for use either as a motor to drive the pump or as a turbine-driven generator. The unit is of the vertical-shaft, alternating-circuit, 3 phase, 60 cycle, 13,800 V, synchronous type and is directly connected to the pump turbine. The motor generator has a thrust bearing and an upper guide bearing located above the rotor, and a lower guide bearing located below the rotor. The entire rotor assembly of the motor generator, shaft, and pump-turbine runner is supported by a Kingsbury-type thrust bearing. This bearing is also arranged for pressure lubrication so that it can support the weight of the rotor assembly on a film of oil when starting in either direction to give a low starting torque. The unit is designed for operation at speeds of 300 and 257 revs. per min. either as a pump motor or as a turbine-driven generator. It is capable of operating as a 13,000 h.p. synchronous motor at a speed of 300 revs. per min, a 10,700 h.p. motor at a speed of 257 revs. per min., as a generator rated 8,500 kW at a speed of 257 revs. per min., and as a 10,000 kW generator at a speed of 300 revs. per min. These ratings are based on operation at 100 per cent. power factor. The unit can also be operated as a synchronous condenser.

The arrangement for obtaining the two-speed synchronous machine is by the use of two electrically independent windings on the stator, either one of which can be selected for use by selector switches and by a rotor winding consisting of 24 poles. For motor operation at a speed of 300 revs. per min. the 24-pole stator windings are used with the 24-pole rotor windings. For generator operation at a speed of 257 revs. per min , the 28-pole stator windings are used and an equivalent of 28 poles on the 24-pole rotor windings are obtained by a special switching apparatus which also reverses the polarity of some of the poles.

The unit is designed and constructed so that it is capable of operation at both speeds and in both directions, but as normal operation will be either as a motor at a speed of 300 revs. per min. or as a generator at a speed of 257 revs. per min., the switching arrangement is only designed to connect the windings for these two methods of operation. All parts of the

(Continued on page 428)

Hydro-Electric Schemes for Yugoslavia

We give a summary of a report issued by the European Office of the United Nations, Geneva

THE United Nations Economic Commission for Europe (ECE), which since 1947 has been concerned with meeting Europe's electric power needs, recently reported on a more than $400 million scheme for the export and transmission of hydro-electric power from Yugoslavia to Austria, Italy and Western Germany.

Detailed plans for the projected works have been worked out by public authorities in the four countries concerned. In a report entitled "Prospects of Exporting Electric Power from Yugoslavia"* expert opinion concluded that it is "economically feasible to export considerable quantities of electric power from Yugoslavia over long periods." They also concluded that such exports could be concentrated during the winter months, which is important because it is during these months that additional electric power is in greatest need in the importing countries.

The group of experts, appointed by the ECE Committee on Electric Power to study the possibility of exports of electric power from Yugoslavia, based their conclusions on detailed considerations of the sites and the basic data for the works which might be constructed in Yugoslavia for this purpose, as well as on their study of the import possibilities of the neighbouring countries interested in the scheme.

The scope of the scheme is indicated by the fact that the "Yougelexport" programme is planned to yield energy which is equivalent, for example, to the total consumption of the Seine Department of France, which includes Paris, and supplies 5 million inhabitants.

The main features of the scheme include the construction on Yugoslav territory of four new power stations and the enlargement of a fifth, together with the construction of a 380 kV transmission network for the export of the power produced, that is 4·3 million kWh. The total capital outlay required is $340 million for the power stations and $70 million for the network.

One possibility which has been contemplated for the realisation of the scheme is the setting up of a company under Yugoslav law for the detailed study and construction of the works, and the establishment of an international holding company outside of Yugoslavia for financing and execution of the contracts.

Various committees of the inter-governmental Yougelexport worked unremittingly on the problem at 32 meetings which were held in 1953 and 1954. Members also visited the main sites proposed for the projected works, and received advice from the four experts supplied by the United Nations Technical Assistance Administration concerning the technical features of the scheme.

One of the main concerns of Yougelexport was to ascertain the potential market, that is, to determine the quantity of power which might be imported by the three neighbouring countries concerned. This enquiry, based on a preliminary estimate of the national requirements of Austria, Italy and the Western Zones of Germany, covered the years 1956, 1957, 1960 and 1970. The maximum load required in 1960 is expected to total 800 MW. The ECE report points out that Austria would balance its imports of winter current by deliveries to Yugoslavia during the summer. The annual utilisation time of the required capacity installed in Yugoslavia would be about 3,000 hours, almost entirely during the winter period.

The Four Projects

In the light of these energy requirements, the Technical Committee of Yougelexport selected the following four projects from the 17 preliminary development projects submitted to it by Yugoslavia, and studied their main characteristics: (a) the development of the Idrijca; (b) the development of the Lika and the Gacka; (c) the development of the Cetina; and (d) the development of the Trebisnjica. The possible output of these plants in an average year, and their construction costs are given in Table I.

The report suggests that it should be possible, three years after financing begins, to make available for export part of the output from the Perucica plant, already under construction. The Yougelexport plan is to install at this plant two new pressure mains and four additional machine sets with a total capacity of 144 MW at a cost of $11 million, thereby making it possible to export 450 million kWh of winter power.

* "Prospects of Exporting Electric Power from Yugoslavia" summarises the more detailed documents made available to governments and United Nations organs and agencies. The summary contains 41 pages including many tables, and in addition maps, charts, and cross sections of the specific hydro-electric projects. Copies of the summary, prepared by the Industry Division of the United Nations Economic Commission for Europe, are available from the Sales Section, European Office of the United Nations, Palais des Nations, Geneva, Switzerland, at a price of $0.50 (U.S.), 3s. 9d. stg., 2 Swiss francs or 160 Fr. frs., or may be ordered through Sales Agents for United Nations Publications against payment in local currencies.

TABLE I. BASIC DATA FOR THE PROJECTS

Project	Installed capacity (in MW)	Possible output in an average year (kWh × 10^6)	Cost of construction (a) (in million U.S. $)	Cost per kW of installed capacity (in U.S. $)	Cost per kWh (in U.S. cents)	Time required for construction (b) (in years)
Cetina	530	2,250	94	177·36	4·18	6
Lika-Gacka	242	920	42	173·55	4·57	5
Idrijca	112	340	46	410·71	13·60	4
Trebisnjica	840	2,300	116	138·09	5·04	6

(a) Figures based on current Central European prices and on the actual results of geological surveys to date.
(b) Taking technical considerations only into account.

The Financial Committee recommended that the various works be carried out in the following order: first, the extension to the Perucica plant; and next, successively, the development of the Cetina, of the Lika and Gacka, of the Idrijca and of the Trebisnjica. The completion of these various works would enable the quantities of power required to meet the established demand to be exported in accordance with a programme consisting of these stages. The Economic Committee, for its part, worked out the distribution among the three importing countries of the power available at each stage—during the years 1957 to 1966.

Transmission System

The export of power in such quantities will clearly require the creation of an adequate transmission system, both in Yugoslavia and the importing countries. The general layout of the network and its development in four stages have been worked out by the Economic and Technical Committees. The details of the lines and their operating voltages have been based on the load to be carried. Only part of the total investment required for construction of such a system will be for the account of exports, since the network will also serve for the transmission of power within the various countries concerned. The share to be finally debited to exports has been worked out and added to the capital required for the construction of the power plants.

The calculation of the average cost of the power produced has been made on the basis of two hypotheses, depending on the period selected to write-off the investment. Since there is, strictly speaking, no international electric power market, and since prices depend essentially on the quality of the power supplied, it was decided to fix the average export price by relating it to the price per kWh produced by a modern thermal plant in the area of consumption. This price varies with the country concerned.

Financial and Legal Problems

The Financial Committee reviewed various traditional methods of financing which might be used. It believed, seeing that the installation of the plant and transmission lines will call for a considerable amount of electrical equipment, to be possible to make arrangements for the medium-term financing of the projects. The Committee felt, nevertheless, that it would be difficult to carry out the scheme as a whole without the participation of the International Bank for Reconstruction and Development or another U.N. Agency which might be created to assist in financing economic development.

Yugoslavia's participation would consist in immediately ploughing back into the scheme its profits from the sale of the power during the construction period contemplated. It was obvious, however, that the most that this Committee could achieve was to provide illustrations, as the formulae finally adopted for financing will depend largely on the legal conditions of the undertakings entrusted with the construction and operation of the plants—a problem that was dealt with by the Legal Committee.

The Legal Committee made a detailed study of the various arrangements which might be contemplated. These ranged from the conclusion of an ordinary contract for power supplies between the companies concerned, to the establishment of a supra-national body whose statutes would be recognised by enabling legislation in each participating country. However, given the legal systems of the countries concerned, it was the conclusion of bilateral contracts between Yugoslavia on the one hand and groups of interested companies in the various importing countries on the other which mainly occupied its attention. As such contracts would always have Yugoslavia as one of the parties, they should contain identical clauses governing the stability and possible revision of prices, and provisions for arbitration, which should preferably be delegated to an international body.

The Legal Committee also suggests that such bilateral contracts might later be compounded and administered by an agency to be set up for that purpose. It would thus be possible to envisage the separate establishment of a company and of an agency. The company, which would operate under Yugoslav law and have its head office in Yugoslavia, would be responsible for the preliminary detailed study and construction of the projects. The agency, with headquarters in a country to be fixed later, could be responsible for the co-ordination and actual administration of the contracts. It could then be constituted as a corporate body and raise loans on the capital market not only in the countries interested in importing electric power, but elsewhere too.

This would make it possible to avoid confusing any credits which might be granted to Yugoslavia for the development of its own economy with those which might be allotted for the completion of the works planned by Yougelexport, such a scheme being, in fact, in the interests of the importing countries as well as in those of Yugoslavia.

Arrangements for Continuing Work

The ECE group of experts in their report stress the "effective co-operation" which had developed between the countries concerned during the execution of the study. While the group considered the task entrusted to it to be completed, it recognised the necessity to maintain liaison between the governments of the countries interested in the execution of the scheme. To this end it recommended that an inter-governmental co-ordination committee be set up under the auspices of the Committee on Electric Power of the United Nations Economic Commission for Europe, to consist of two representatives from each of the following countries:—Austria, Italy, Western Zones of Germany and Yugoslavia.

It was proposed that the ECE Electric Power Committee, which is now holding sessions, should provide the following terms of reference for the Co-ordination Committee: "to study in the light of developments in the situation, the various arrangements which might be envisaged for the execution of the scheme; to facilitate the negotiation of inter-governmental agreements to match the bilateral contracts concluded between the undertakings of the countries concerned; and generally to co-ordinate the study and execution of the several stages."

Mining Type Telephone. Ericsson Telephones Limited, Nottingham, have issued an illustrated brochure on their Type N2986 magneto mining type telephone designed for underground service.

The Economic Availability of Wind Energy

Percy H. Thomas presents further data to show the potentialities of a combination of wind and water power in providing firm power for electric utility supplies

THE present article is supplementary to that by the writer in the April, 1955, issue of this journal, "Characteristic Wind Patterns and Electric Utility Supply," and is intended further to elucidate his proposed ways and means for exploiting wind energy to secure *firm* power in suitable electric utility systems. This second article is made pertinent at the present time by the letter to WATER POWER from M. H. Duquennois, printed on page 339 of the September issue. A paper by him before the Brazilian Sectional Meeting of the World Power Conference in 1955, pointing out the conspicuously complementary character of the patterns of stream flow and wind energy in Algeria was the occasion of the author's April article. In his letter M. Duquennois points out that wind power should be sought as a source of firm utility power, not merely as a means of saving fuel. Further he urges that researches on such wind use should by no means be slackened on account of the advent of nuclear energy.

With this point of view in mind, what follows is to be applied primarily in our present widespread utility networks having a portion of hydro storage, and with an appropriate number of aerogenerators of the type here under consideration (7,500-10,000 kW capacity) dispersed over the more windy portions of the area and preferably located adjacent to load centres, so that the bulk of the wind energy is consumed near by. It is further here understood that the capacity sought from the wind will not exceed some economic limit, which may be taken here as 25 to 30 per cent. of the system total.

Under these conditions energy, generated as the wind blows by the individual wind units, is delivered into the utility network, where it is added to all the other generation and completely loses its identity. As is usual, consumers are supplied from this pool of energy, it being assumed that the network circuits are properly fitted to the patterns of the generation and the load characteristics of the system. The justification for these statements is found in the April article and further support is given below.

Starting with the definite stability of the total of the annual wind energy as extracted from the winds by aerogenerators (no variations in the annual totals greater than 10 or 15 per cent. below the long-time average being expected), and noting that the pattern strongly emphasised by M. Duquennois, namely, that the variation of wind generation from month to month through the year on the average is approximately opposite to the pattern of the stream flow, where the low-water deficiencies of hydro tend to be balanced out by a proper capacity of wind units, it becomes clear that the equalising of the wind variations beyond the short-time vagaries of the wind at individual sites is not in the interest of efficiency. The importance of this relation of wind and stream-flow patterns should be emphasised, for, if the installation of wind units be perfectly fitted to the hydro-generation pattern, the total available firm capacity of the two sources would be the sum of their *average* annual capacity, whereas for separate operation this would be the sum of the two minima. How far such a co-ordination can be attained in particular cases is a matter for future determination. It may be added, as bearing on this matter, that the writer has estimated that in the U.S. the tendency is for more or less two-thirds of the wind energy to fall in the six months, November-April.

To show how this equalisation of the short-time variations of the wind works out, the writer made an exhaustive study of a large area of the U.S., east of the Mississippi River, extending from Vermont to North Carolina (see fourth Fed. Pow. Com. 1954 monograph) based on the synoptic wind-velocity readings of the Weather Bureau in 34 scattered stations. The amount of energy extractable by aerogenerators from the reported average velocity for each station was worked out for each hour of the 30 days of the month of November, 1941, 25,000 readings, and the results were summarised in eight geographical groups, and for the area as a whole. The accompanying table shows for each day of the month and for each group, the average hourly energy, in arbitrary units. The tabulations are incomplete.

It is seen that the minimum average hourly energy for one day for the area as a whole was 56 units, 40 per cent. of the hourly average for the month 138·2 units. The longest period during which the hourly average remained below the month's average was four days for the area as a whole, and the same was true for all but two of the groups. The highest hourly average for the area was 175 per cent. of the month's average. From another table of the study it appeared that lowest four-hour daytime average (9 a.m. to 6 p.m.) of the month for the area was 21 per cent. of the month's average, and this is taken as the diversified firm capacity of the area for the month, a basic figure, this being without the aid of storage. This 20 per cent. of capacity further does not require auxiliary capacity for firming the energy, the capacity of the aerogenerators feeding directly. The average energies of the several groups for the month are surprisingly uniform, ranging from 127 to 143, the average being 138·2. This tabulation is thus very informative and shows the important effectiveness of diversity.

An example of the functioning of hydro storage in equalising the short-time vagaries of the wind may be

based upon the same table, as shown in the accompanying chart. The three curves of this chart, show, for the area as a whole, respectively, (1), A conventional load curve, with the peaks of week-day, Saturday and Sunday in the ratio of 3, 2·5, 2 respectively. (2), The variations of the volumes of energy stored in the reservoir necessary to fit the generation delivery to the load. (3), The pattern of the generation of the energy by the wind as shown in the table. The total of the load is made equal to the total of the generation of the month. This is a most interesting and important set of curves. The range in the daily volume of stored energy is from 165 arbitrary units upward to 226·4 units downward, a total use of storage of 391·4 units. This storage capacity is equal to 9·3 per cent. of the wind energy delivered, and is equal to 2·8 days' storage in the 30 days' operation.

It is seen that the reservoir level returns to normal several times during the month. The several separate group curves of the F.P.C. monograph show only two in which the reservoir level does not pass at least once through normal during the month. It thus appears in this rather exhaustive analysis that 10 per cent. of the month's output is sufficient capacity to equalise the operation. It is not assumed that this figure applies to all cases, but until better information is available it will serve very well for studies.

TABLE I 24-HOUR AVERAGES OF RECOVERABLE ENERGY (CUBES OF VELOCITIES) FOR EIGHT GEOGRAPHICAL GROUPS

November 1941	A	B	C	D	E	F	G	H	Area
1	109	201	254	266		252	328	298	243
2	76	138	235	204		203	319	246	203
3	143	101	156	109		70	75	51	102
4	105	56	88	60		42	39	40	61
5	57	*23*	*18*	69		96	56	73	*56*
6	56	117	104	166		180	142	161	132
7	172	155	220	228		243	334	336	241
8	245	75	248	101		143	272	189	182
9	113	88	73	92		145	92	77	97
10	*30*	65	85	98		158	129	113	97
11	117	89	178	155		167	188	143	148
12	191	242	185	237		162	171	97	184
13	48	42	72	78		48	140	153	83
14	140	88	79	*31*		77	76	46	77
15	111	69	124	66		*34*	84	105	85
16	174	213	176	224		206	112	62	167
17	182	154	44	79		118	39	45	94
18	61	216	113	82		67	78	106	103
19	74	138	112	81		88	68	135	99
20	312	252	236	217		180	223	266	241
21	250	254	262	273		241	210	152	235
22	45	79	54	70	*59*	119	41	53	65
23	164	166	124	128		124	209	76	142
24	200	231	177	286		356	138	81	210
25	164	78	128	126		135	85	138	122
26	301	195	299	203		117	265	238	231
27	151	187	126	167		98	165	120	145
28	148	103	45	*31*		35	*25*	*14*	*57*
29	224	176	161	89		64	98	131	135
30	128	167	75	178		85	64	58	108
Average	143·0	138·6	141·7	139·8		135·1	141·9	127·0	138·2

Minimum values italicised.

Figures are proportional energy values, in per cent., corrected to a station velocity of one mile per hour.

For a numerical illustration, assume that 100 aerogenerators (10,000 kW capacity) are scattered over an area having the characteristics of M. Duquennois' home country, France, with units located along the Atlantic and Channel coasts, famous for "windiness," and at favourable sites in the high mountains in the east and south. At 50 per cent. load factor these would deliver 4,380,000 MWh annually into the system. The amount of storage required to equalise the short-time vagaries of the wind, assuming the data of this study to apply, would be 10 per cent. of 4,380,000 MWh divided by 12 = 36,500 MWh. To store such an amount of energy in reservoirs having 35 m. effective head (115 ft.), would require about 350,000 acre-feet of storage, a very modest amount. Assuming that the

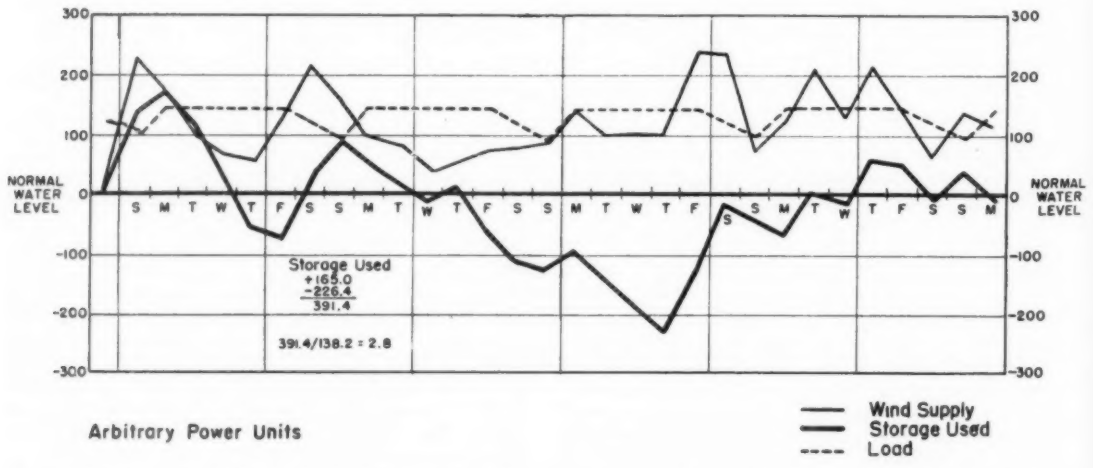


Fig. 1. Wind supply, hydro storage and conventionalised electrical load for the area covered by Table I

wind energy supplies 25 per cent. of the system capacity, this layout represents 4,000 MW at 50 per cent load factor.

In addition to this 4,000 MW is 200 MW of firm wind power capacity coming directly from the aerogenerators, firm from diversity alone, without benefit of storage, as pointed out above.

It remains to point out that small scattered reservoirs, such as pondages, utilising however only their storage capacity over and above the requirements of their normal duty, are more favourable for equalisation than the seasonal reservoirs on account of their dispersion. Also, that the use of seasonal reservoirs for this short-time equalisation, (leaving the reservoir level unchanged at the end of a short time) will not usually interfere with the normal use of the capacity.

Of special interest at the present moment is the check on the estimates of cost and performance of the writer's aerogenerator, $127 per kW for the 7,500 kW estimate and $102 per kW for the 10,000 kW, see the April article. Some further information will be of interest here. The all-important feature of the design is the aerodynamic treatment, upon which there is a very wide discrepancy in the literature. For example, Fred E. Weick, an N.A.C.A. expert, in his book, "Aircraft Propeller Design" gives two procedures for the computation of his propellers as then used, both of which yielded reasonable results. When applied to the high-efficiency wind turbine, however, they give results differing by several fold, one yielding efficiencies uneconomical compared with present power costs, whereas the other shows the costs given above. This is not the place to pursue this matter and reference is made to the Federal Power Commission monograph, "Aerodynamics of the Wind Turbine, 1949" or to the writer's paper at the Oklahoma A.I.E.E. meeting, Oklahoma city, printed as Technical Paper No. 41 in the records of the Organisation for European Economic Co-operation, Working Party No. 2, 1952. The poor economic showing of the Smith-Putnam turbine no doubt resulted from the use of the inapplicable procedure.

Steel quantities in the writer's design; tower 644 short tons; revolving bridge, without wheels, 333 tons; two wheels 176 tons; light metal; framing in wheels 10 tons; cowling for the wheels and the generator room 10 tons. Total weight of aerogenerator 1,400 tons. The cost of the tower (475 ft. high) about 20 per cent of the total.

Significant special equipment; generator; inverted rotary; transformer; switchgear; rotary means for the bridge; 50 ft. turntable under the bridge; two emergency friction brakes on the wheels; two main bevel gears, each 4,000 kW, ratio about 12, pinion speed, 52·5 r.p.m.

Perhaps the unique part played by hydro storage in these complex networks will be seen in better proportion from a brief generalisation of their operations as a whole. In addition to the functions of generating and distributing power, they serve to adjust the amount of character of the supply to the needs of the consumers. In this duty the system must meet an almost infinite series of variations in operating conditions:—changes in the demands of consumers, variations in the supply of hydro energy, in fuel supplies, in the contributions of individual generating units, in the circuit conditions, etc., some variations being normal and expected, others accidental and unpredictable. The system controls the momentary changes by automatic governors on the generators, other changes partly automatically but more generally by manual manipulation by the operators, using numerous instruments and indicators.

Storage reservoirs constitute a very useful facility, by the seasonal storage of power, by facilitating peaking of energy, by week-end storage, by permitting the orderly transfer of stored energy from one part of the systems to another at times of low loading of the lines, and in systems utilising wind power as here contemplated, by equalising the short-time vagaries of the wind at local sites, as shown on daily weather-bureau charts. The point here made is that this last service, for firming wind energy, may be performed by existing storages without materially interfering with their other functions in a great majority of cases, and that in any case the volume of energy storage required is likely to be unimportant in the overall operations.

M. Duquennois makes the very timely statement in his letter, that the advent of nuclear power by no means inhibits the beneficial use of wind power. There seems to be at the present time a semi-conscious, but entirely unwarranted, assumption that the nuclear power plant is the ultimate perfect source of electric power. However, experienced power engineers who " have their feet on the ground " will understand that this is far from the present situation. The economy of this type of power over other available types remains to be determined, but the fact that its use is fraught with great difficulties and serious dangers is evident enough. While in some uses involving transportation of various sorts, nuclear energy offers the opportunity to carry along large quantities of energy in small bulk, though at the cost of much special construction, in the supply of utility power its chief advantage seems to be a large saving in the cost of fuel, but without any corresponding reduction in the total cost of power at the busbar, on account of the increased cost of installation. Its claimed advantage seems to be somewhat of a paradox.

By contrast, wind energy operating in a network, on a proper scale, has in completeness what nuclear energy can claim only in part, namely, power continuously available on the site, not dependent on transportation, and free from danger of interruption by catastrophies or human intervention; and the wind energy is free and exempt from inflation and monopoly manipulation. It is entirely safe and free from threat to the surrounding community; it has no fall-out or poisonous products.

Finally, wind power as here proposed, according to the writer's estimates, will have a power cost, either per kW or per kWh, of the order of a half to a third of the power costs anticipated for nuclear energy, at least in the U.S. and comparable areas.

Surely, M. Duquennois is right; the advent of nuclear power, if and when it arrives, should not slow down efforts to exploit the power of the wind.

ECE Working Party for Russia. The Working Party for the study of rural electrification of the United Nations Economic Commission for Europe (ECE) has been invited by the U.S.S.R. to spend two weeks in the Soviet Union.

Fig. 1. The Duduma Falls on the Machkund river

The Machkund Project

An account is given by R. Dorai Rajan of the first hydro-electric development in the newly formed Indian State of Andhra

THE Machkund hydro-electric project in the new Andhra State was switched on by President Rajendra Prasad on August 19. It marks the beginning of water-power generation for this youngest State in India, which till now has been served by thermal units, and will form an intermediate link in a future all-India grid. For want of natural sites in the state, it has not been possible to provide earlier hydro-electric projects of any magnitude, and even the Machkund project is located in the northern tip of the State on the Eastern Ghats, which are not so favourably situated as the Western Ghats for power development.

This project utilises the waters of the Machkund river at a place 54 miles from its source. The river forms the boundary between Andhra and Orissa States, and the power house is situated on the right bank of the river at the Duduma Falls (Fig. 1) where a head of 550 ft. is available. The project site is in the heart of a malarial jungle, 120 miles from Vizagapatam on the Eastern Railway and 81 miles from Bobbili, the nearest railhead, on the western slopes of the Eastern Ghats. The Machkund river ultimately joins the Sabari river which in turn flows into the Godavari river. The catchment of the basin at the diversion dam is 858 square miles.

The scheme will be worked in partnership between the Andhra and the Orissa States, the capital outlay and power being shared by agreement on a 70:30 ratio. The first stage of the scheme, now nearing completion, provides for an installed capacity of 51,000 kW. It is being executed under the direction and supervision of the Andhra Government, who will also operate it. With the separation of the Andhra State from October 1953, the scheme went to the new State.

where larger power schemes on Godavair and Krishna rivers are also planned. The transmission lines, however, are constructed by individual States.

The scheme (Fig. 2) provides for a main storage by a masonry dam, a diversion dam some 17 miles below the main dam, a flume channel, a free-flow tunnel, a pressure tunnel, a tunnel pond forebay and three penstocks to the power house to feed three 17,000 kW generating units.

The main dam at Jalaput (Fig. 3), 1,220 ft. long, 148 ft. above deepest foundation and 18 ft. wide at the top, impounds a net capacity of 25,400 million cu. ft. on the Machkund river at a point two miles below the confluence of its chief tributary, the Patal Arm. The dam is a solid gravity non-overflow structure built of random rubble in cement mortar masonry and the volumetric content of masonry is 12·5 million cu. ft. On the flanks, corewalls of suitable length are provided for connecting the dam with the rocky hillside. The overflow channel is located on a low saddle on the right flank, the length of the spillway being 550 ft., with eight gates of 60 ft. by 20 ft. by Dortmunder Union, Germany, to discharge a maximum flood of 149,000 cusecs. A drainage gallery, 7 ft. by 5 ft. is provided for the full length of the dam excepting the corewalls. Contraction joints commence from 5 ft. below the drainage-gallery level. Three steel discharge pipes, each 8 ft. 6 in. in diameter, are built into the dam for discharging power water into the river, and will be used for developing a maximum power of 20,000 kW at the dam site when required. Each of these is capable of discharging 1,125 cusecs at full reservoir level. Two 8 ft. 6 in. scour pipes are also provided near the power pipes to keep the intake clear of silt. The butterfly valves and the hollow jet valves for the pipes were supplied by Neypric, France. The dam will be completed by the end of next year.

The water from the reservoir is allowed to flow along the course of the river according to requirements and is picked up at the diversion dam (Fig. 4), 17 miles below and half a mile above the Duduma Falls. This dam is also of the gravity type in solid masonry, 1,030 ft. in length, having a central spillway 560 ft. wide with eight 60 ft. by 20 ft. crest gates by

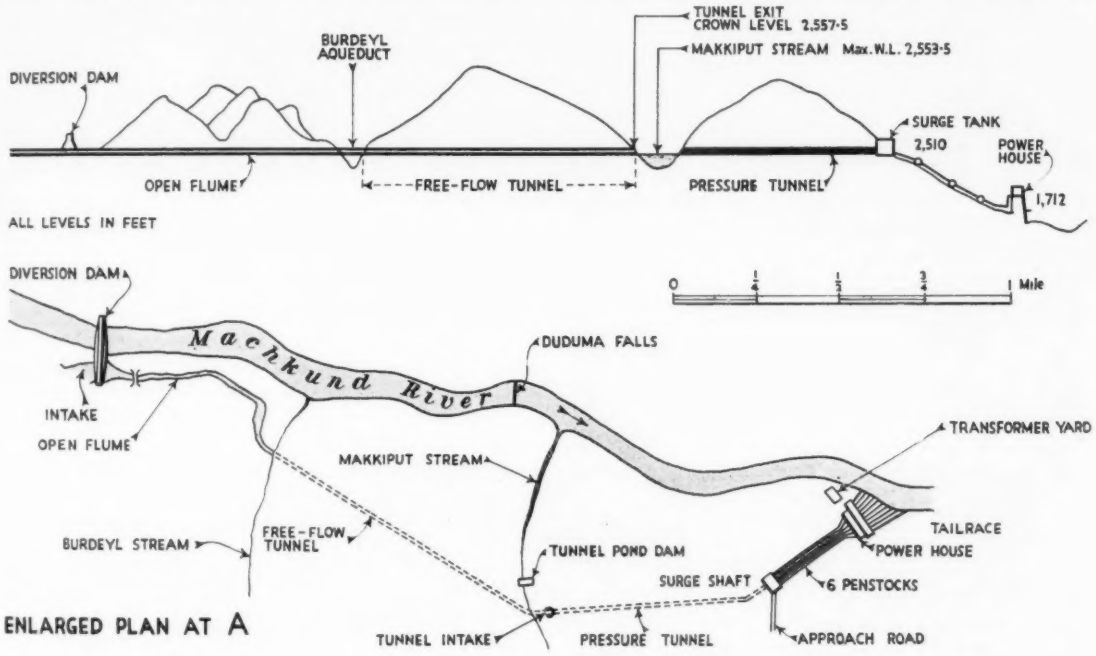
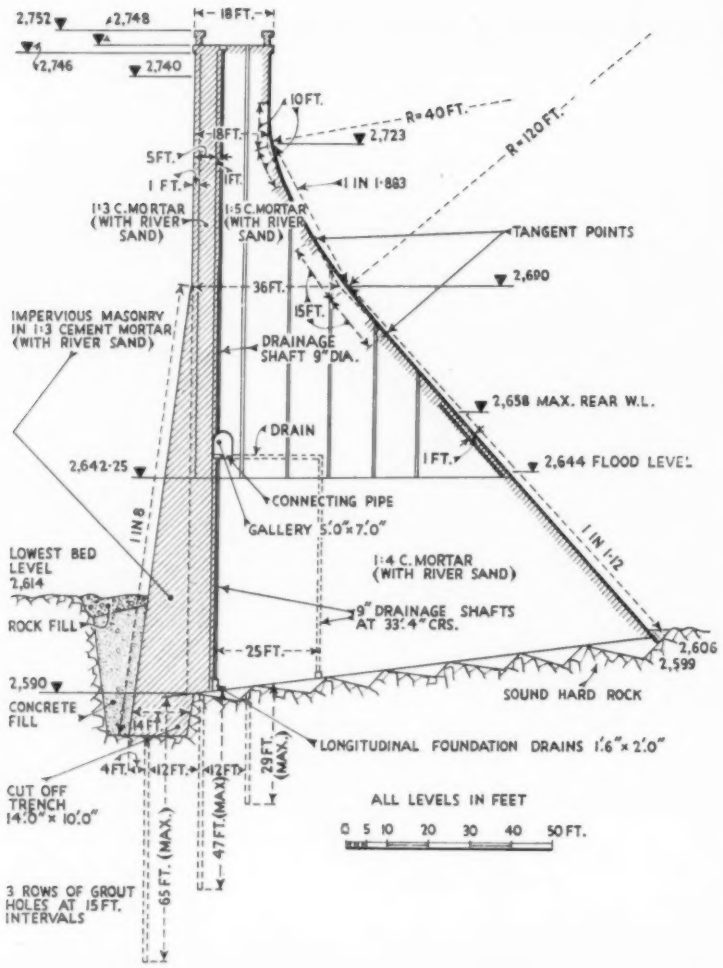


Fig. 2. Profile and site plan of the Machkund hydro-electric development



Ransomes and Rapier Ltd., 50 ft. above river bed, to pass a maximum flood discharge of 185,000 cusecs at a depth of 18·4 ft. above crest level. The dam will store 389 million cu. ft. of water for regulation and balancing. The height of the section above the deepest foundation is 83·5 ft. with a bottom width of 68·5 ft. and a top width of 10 ft. Contraction joints are provided at 100 ft. intervals. The total masonry content of the dam will be about 2 million cu. ft.

The offtake is controlled by two Ransomes and Rapier sluices, 12 ft. by 8 ft., each capable of a peak discharge of 1,800 cusecs, and a 12 ft. by 8 ft. scour sluice, also supplied by Ransomes and Rapier Ltd., is also provided to clear the silt deposited in front of the dam due to the wasteful method of cultivation practised by hill tribes in the basin above.

The water from the diversion dam is conducted along an open concrete-lined channel (Fig. 5), 4,034 ft. long (including a 334 ft. reinforced-concrete aqueduct, Fig. 6), skirting along hill slopes

Fig. 3 (left). Cross section of the main dam at Jalaput

Fig. 4 (below). A general view of the diversion dam under construction, showing the river diversion

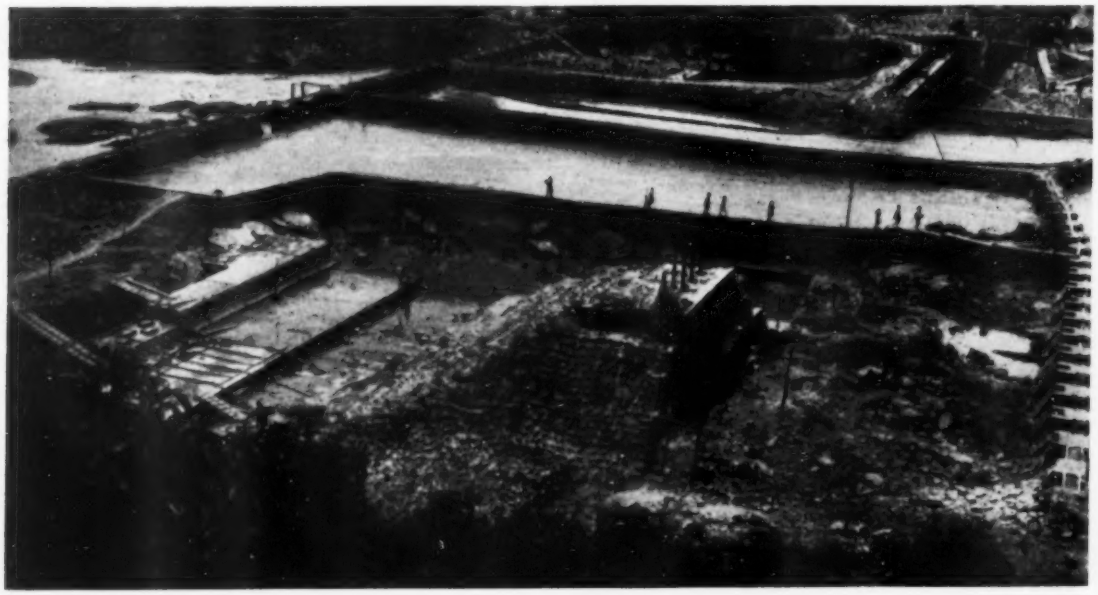


Fig. 5. Excavation of the flume channel in progress in ordinary soil

on the right bank of the river and thence through a free-flow tunnel 4,010 ft. long with a sectional area of 238 sq. ft. and capable of a peak discharge of 1,800 cusecs into the Makkiput stream valley, where a regulating pond is formed by building a small "tunnel-pond dam" (Fig. 7) 442 ft. long and 66 ft. above deepest foundation with an effective capacity of one million cubic feet of water at full reservoir level. This dam has a central spillway 250 ft. wide with non-overflow sections and corewalls at either end. The crest of the spillway is 50 ft. above the river bed and the top of the non-overflow section is 8 ft. above the spillway. The bottom width of the dam is 51·5 ft.

A concrete-lined pressure tunnel (Fig. 8) takes the water from the tunnel pond and delivers it at the penstock head. The cross-section of the tunnel, which is in the shape of a horse-shoe, has an area of 185 sq. ft. This tunnel is 7,010 ft. long and is the longest constructed for a hydro-electric scheme in both Madras and Andhra States. It cost Rs. 80 lakhs, including construction machinery, and was completed by John Mowlem and Co. Ltd., London, ahead of schedule.

The tunnel ends in a surge shaft 75 ft. high and 50 ft. internal diameter, cut in rock. Two steel pipes 10 ft. internal diameter and 140 ft. long, lead from the surge shaft and are laid in a small concrete-lined tunnel. They are controlled by intake gates supplied by Dortmunder Union, Germany. At the end of these two pipes are installed two trifurcating manifolds 120/60 in. by 66 in. by Boving and Co. Ltd., with air valves and metering equipment.

Three steel penstocks, supplied by Ferrum of Poland, 63 in. in diameter for a length of 770 ft. and 57 in. for the balance of a total length of 1,504 ft.

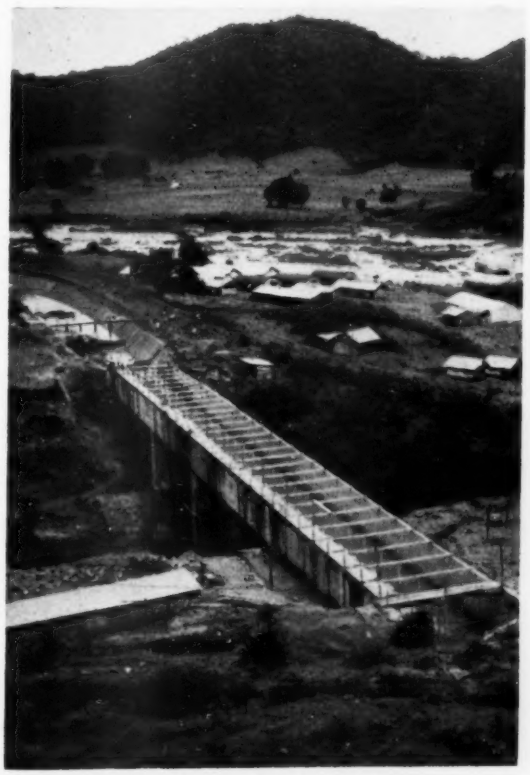


Fig. 6. The Burdeyl aqueduct

and varying in thickness from 11 to 37 mm., are taken from one of the manifolds. They are carried on saddles, and have high-pressure valves, supplied by the English Electric Co. Ltd., near the power house.

The three remaining penstocks will be added in stages depending upon load development. A haulage track runs along the penstock tracks for the transport of men and material from and to the approach road to the power house. The winch for the haulage was supplied by W. B. Wild and Co. Ltd., Birmingham, England, and haulage track material was supplied by Robert Hudson and Co. Ltd., England.

The power-house building (Fig. 9) is a steel-framed structure with coarse rubble masonry walls in superstructure, 295 ft. long, 60 ft. wide, and 65 ft. high from the generator floor level, and is designed to accommodate all the six generating units of the final stage development and a house-service unit with a repair bay at one end. An annexe at first-floor level is provided for housing the main switchgear, and the battery room, store room and low-tension switchgear are on the ground floor. The machine hall is traversed by an electrically operated 100-ton crane supplied by Demag, Germany. The substructure of the machine hall consists of reinforced concrete walls 6 ft. thick taken down to the foundations 46 ft. below the main floor level. The cooling water and Mather and Platt "Mulsifyre" pumps are located in a small extension at the eastern end of the power house below ground-floor level, the supply to these services being taken from the tailrace pool.

For the first stage, the principal units consist of three Morgan Smith vertical Francis turbines rated at 25,000 h.p., 600 r.p.m., coupled to 17,000 kW Westinghouse generating units (Fig. 10). The house-service unit is a Morgan Smith single-nozzle single-overhung-runner horizontal impulse turbine to develop 600 h.p. at 750 r.p.m. coupled to a 500 kVA two-bearing-type horizontal generator. The tailwater from the power house joins the Machkund river about two miles below the diversion dam.

The outdoor transformer yard, 204 ft. long and 91 ft. wide, is located by the side of the power house, and contains ten 6,670 kVA, 11/132 kV single-phase transformer units arranged in three banks each bank forming a unit, one unit being spare. These transformers are connected in delta on the 11 kV and star on the 132 kV side and the neutral of the star winding solidly earthed. High-speed oil circuit breakers are provided for controlling the 132 kV lines. The transformers are by Ferranti Limited, and the outdoor switchgear by The British Thomson-Houston Co. Ltd.

The power generated at Machkund is transmitted by a double-circuit 132 kV transmission line (Fig. 11) via Vizagapatam as far as Nellore district, a distance of about 450 miles, serving on the way East and West Godavari, Krishna and Guntur. A third goes to Berhampore in Orissa. Power will be stepped down to 33 kV and 11 kV at Vizagapatam, Rajamundry, Vijayawada, Bhimadolu and Nellimarla for distribution.

The existing steam stations at Vijayawada and Vizagapatam with plant extensions will be retained

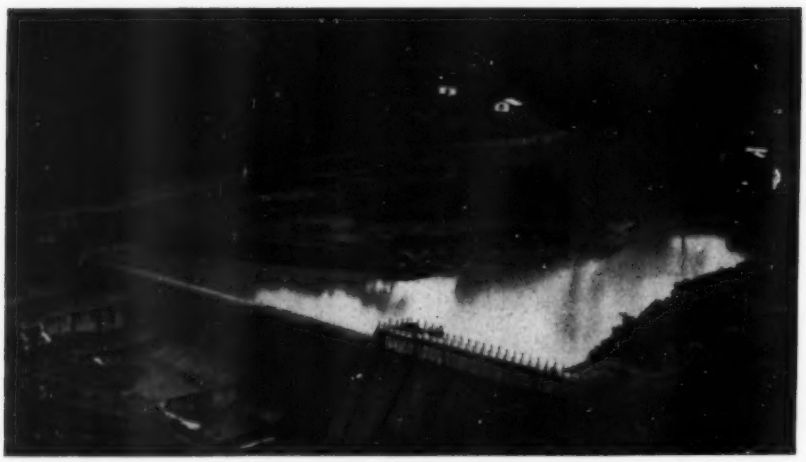


Fig. 7. A view of Tunnel Pond dam on the Makkiput stream, forming the connection between the free-flow and the pressure tunnel

Fig. 8. Interior of pressure tunnel, with finished concrete lining and partly completed invert

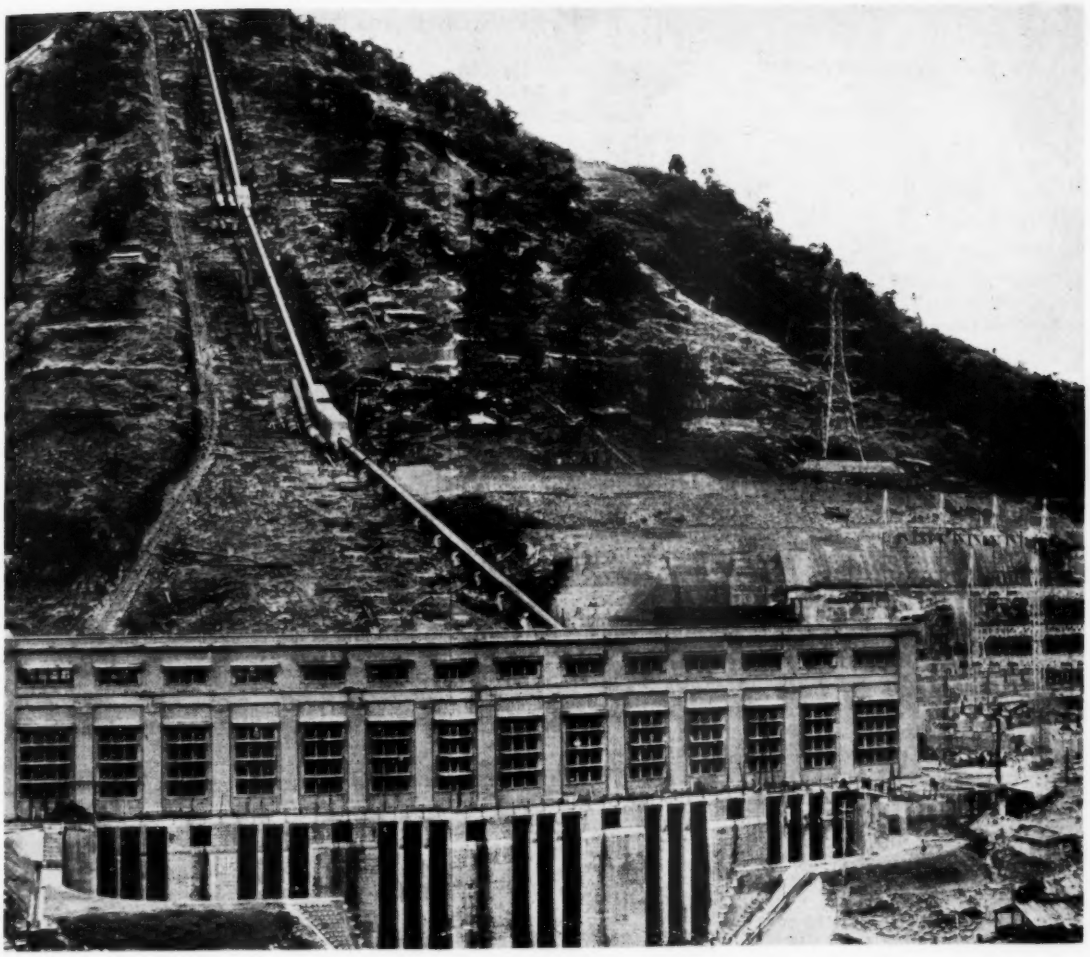


Fig. 9. Machkund power house under construction

as standby in the event of low water conditions in any year or to increase the total power output to meet unforeseen load increases in advance of completion of any of the stages of development.

The construction of the transmission line across the Godavari river near Rajamundry for a distance of nearly four miles provided a major problem for solution. The entire crossing is spanned by 18 towers including the terminals, which are located outside the flood banks of the river. Thirteen out of 18 towers are of a special type carrying three circuits, two of 132 and one of 33 kV. Ten towers lie on the river bed and are subject to deep scour. Well foundations with eight wells for each location arranged in two rows have been adopted for these towers. The river-crossing towers carry in

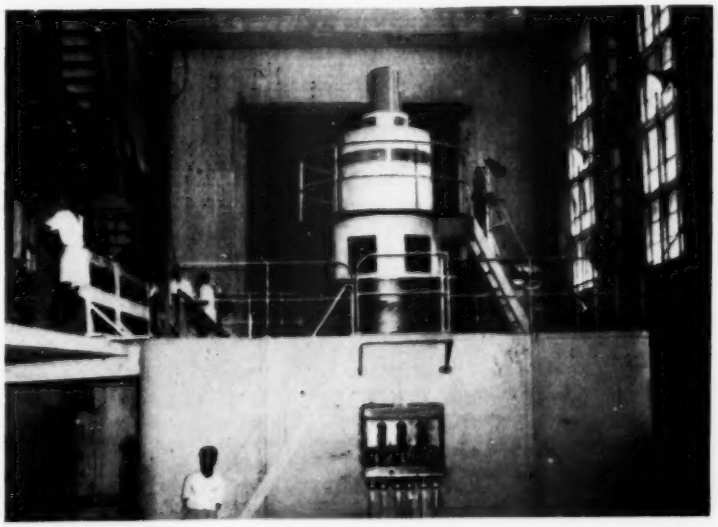


Fig. 10. No. 1 generator ready for service

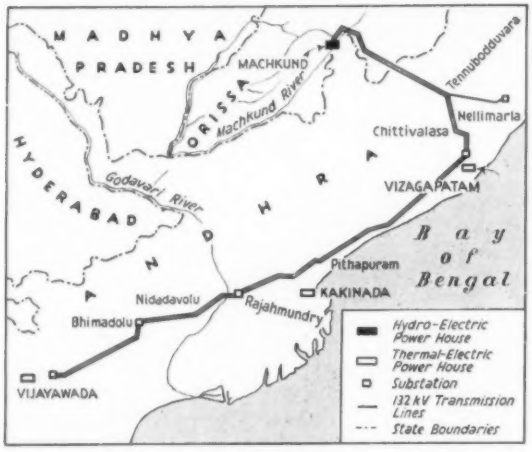


Fig. 11. Transmission system from Machkund

addition, a pair of "Hardex" telecommunication earth wires for the telephone system, the armouring of the cable serving as earth conductor for the four-mile crossing. The transmission lines were constructed by the British Insulated Callenders Cables Limited, S.A.E., Italy, and Crompton Parkinson Limited. The substation equipment was supplied and erected by Reyrolle & Co. Ltd., Associated Electrical Industries Ltd., and the English Electric Co. Ltd.

To facilitate an efficient system of control and operation, carrier-current communication has been installed.

Considering the inaccessibility of the project site, 120 miles from the nearest railhead, scarcity of labour, severe weather conditions limiting the working period to nine months in the year, and the incidence of malaria, a new record was set up by advancing the target date by one year.

Machkund power will contribute to the speedy industrial development of the Andhra State because large blocks of power will be utilised by Vizagapatam harbour, the Caltex refinery, the fertiliser factory sponsored by the Government of India at Vijayawada, the ferro-manganese industry to be set up, and further cement factories.

Among the engineers who were engaged in the construction of the scheme were Messrs. P. M. Chengappa and A. Venkateswaran, Superintending Engineers under Mr. S. R. Krishnamurthi, Chief Construction Engineer, and Mr. B. R. Somayajulu, Chief Engineer for Electricity, Andhra.

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in the Hol-Hallingdal valley is on a 20 kV system supplied initially by the temporary station at Djupedal. This has now been supplemented from Ruud, where a 20 kV supply has been made available from No. 2 generating set through an 8,000 kVA transformer. The 20 kV bars can also be supplied from the 220 V house-service supply through an 800 kVA transformer, and a reserve supply is brought in at 200 kV from Djupedal.

The central control room, part of which can be seen in Fig. 20, was equipped by NEBB. Along the front wall is the main control board carrying a mimic diagram of the penstocks, the 9 kV and 220 kV system, and the necessary indicating instruments and alarm signals. In front of this board is a control desk which provides for remote control of the penstock valves, semi-automatic starting of the turbines, automatic synchronising, and control of the alternators. Along the rear wall is a board controlling the 20 kV and house-service supplies. A 20-line private telephone exchange is also installed in the control room, together with a high-frequency carrier-current telephone to Sogn substation near Oslo, and a public telephone.

Voltage regulators, meters and protective relays are located in a separate room. Generator protection covers stator earth fault, overload, over-voltage, and differential protection, and in addition signal relays keep a check on bearing temperatures, bearing cooling-water circulation, oil circulation, governor oil pressure, operation of spare governor-oil pump, water level at the leakage pumps, and stator temperature. Transformer protection includes Buckholz-type relays and later will include differential protection. Indicators keep a check on transformer-oil temperature, oil level, and the operation of the cooling fans. On the 220 kV system impedance relays are installed, and a new type of high-speed relay is to be installed on the transmission line to give a total opening time (relay and breaker) of 0·12 to 0·15 sec.

(To be continued)

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motor-generator unit are designed and constructed to withstand a runaway speed of 555 revs. per min. in either direction. The motor generator was designed and built by the Allis-Chalmers Manufacturing Company.

Operation of Pump Turbine

To date the pump-turbine unit has been used most of the time as a pump because its primary function is to store water in the Carter Lake Reservoir. However, it is also used as a turbine whenever it is necessary to deliver the water stored in Carter lake to the Horsetooth feeder canal. As a pump the motor is started at full voltage with the impeller unwatered by means of compressed air to reduce the duration of the disturbances of the electrical system. After the unit is synchronised, the air is released and the discharge butterfly valve is opened. The unit is started as a turbine by partially opening the butterfly valve and using the bypass valve as a vernier to obtain synchronous speed. The main circuit breaker is then closed and the butterfly valve opened fully to load the unit. To stop the unit the butterfly valve is closed before opening the circuit breaker.

Initial operation of the reversible pump-turbine at the Flatiron plant has shown good performance both as a pump and as a turbine. Preliminary results of field tests using the salt velocity method indicate that all guaranteed efficiencies will be exceeded. Present indications are that reversible units of this type will find increasing applications in modern hydro-electric systems.

Tri-Dam Power and Irrigation Project

IAN B. MACKINTOSH, M.A., A.M.I.C.E., gives brief particulars of a scheme which is in progress in Sonora, California

TRI-DAM project is a development of the Stanislaus River in the Sierra Mountains area of California, the joint owners being the Oakdale Irrigation District and the San Joaquin Irrigation District. The initial contract for only two of the three dams, together with associated works, was awarded to a group of contractors headed by the Morrison-Knudsen Company, Inc., of Boise, Idaho, on May 23, 1955, for some $31 million. The works are located in the Stanislaus National Forest, a hunting and fishing area 40 miles north-east of Sonora, California. The third dam, Tulloch dam, is expected to be constructed later.

The prime purpose of the project is the irrigation of certain areas of the two districts but power will be produced. The scheme is being financed by the sale of bonds, and these bonds will be repaid by revenues from the power, a firm contract for the sale of which has been signed with the Pacific Gas & Electric Company. This contract takes account not only of the energy from the new projects but also the benefits which will be enjoyed by downstream plants due to the improved regulation. There are two quite separate parts of this project, namely, the Donnells development and the Beardsley development. The works are one of the few now under construction in the field of power and irrigation which are being undertaken by private agencies.

Donnells

Donnells dam and power house is a high-head development and will have a working head varying between 1,300 ft. and 1,500 ft., and will be equipped with a single unit of 54,000 kW capacity. The dam is to be of the concrete arch type and will be located in a narrow canyon at 4,630 ft. elevation. The length will be 750 ft. at crest which will be 290 ft. above the river bed. It is estimated that excavation for the foundations will be 170 ft. below the river bed in a narrow cleft. The quantity of concrete required for the dam will be 200,000 cu. yards. A 7½-mile long pressure tunnel, 13 ft. in diameter, will lead to a surge shaft and thence to a steel penstock down the mountainside to the power house. The tunnel invert only will be lined with concrete as the rock is sound granite. Driving will be from two adits. The main contract will include the installation of the turbo-alternator and all electrical equipment.

Fig. 1. Donnells dam site, looking upstream

The terrain is rugged and access to the dam site very difficult. The nearest access is by a roundabout route which, rising to an elevation of 7,000 ft., is commonly covered with 12 ft. of snow in the wintertime. To avoid being dependent on this route, which is in any case in poor condition for much of the way, the contractor has elected to construct a new road at an elevation of 4,700 ft. for a distance of 7½ miles along the river. Over a length of about two miles near the dam this road will have to be cut out of the steep rock faces.

No suitable gravel or sand is available and all the aggregate needed will be crushed from quarried material. Almost any of the rock near the dam is suitable but in the very steep ground, which rises 800 ft. above the dam, it is going to be a problem to blast without danger. The crushing plant is to be built into the mountain. The graded materials, from 6 in. size downwards, will be stored in bins 40 ft. high and 32 ft. in diameter. Specifications require that concrete between given elevations shall not be placed at a higher temperature than 45° F., 50° F.

and 55° F. To achieve this requirement cold air from a refrigeration plant will be passed through the coarse aggregate in the bins when required. Weigh batching will be done in the reclaim tunnel under the bins; this will result in a considerable saving in the size of the mixing-plant structure which does not have to contain storage hoppers and weigh-batching facilities.

The concrete will be handled by an 8 cu. yard capacity cableway having a span of 1,100 ft. A movable tower on a track, 700 ft. long, situated on the same side of the canyon as the mixing plant, will house all the hoisting machinery and carry one end of the main gut; a concrete anchorage high on the opposite cliff will provide the other support. The mixing plant will consist of two 4 cu. yard capacity tilt-type mixers and these will be discharged simultaneously into an 8 cu. yard bucket which will be carried to the cableway by a large diesel-electric car running on a railway track. The cars will have space for two buckets and two cars will be in use. The capacity of the concrete facilities will be 120 cu. yards per hour. Communications will be by short-wave radio between the cable-

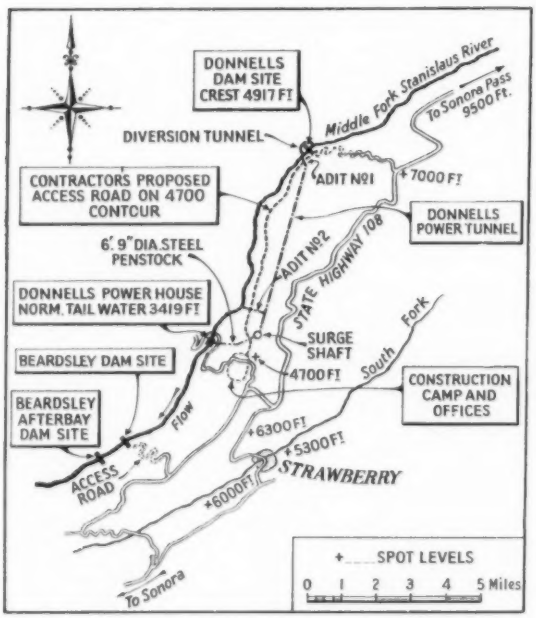


Fig. 2. Sketch map of the Tri-Dam project

way driver and the point of placing; a television screen above the driver's head may be used to show him his hoisting cable and drum, thus telling him when his load has come to rest after he has applied the brakes. This method was used successfully at Table Rock dam. The gates on the bottom-opening bucket will be operated by compressed air by coupling up a compressed-air line, from below, to the bucket.

The small amount of concrete required in the dam, only 200,000 cu. yards, limits the total money that may be spent on the plant. A much greater economy in materials and labour is imposed than would be the case if, for instance, there were over a million cubic yards to be placed. In that case money spent on the refinements of a plant in adding to the convenience of layout would pay off during the life of the project.

Fig. 3. Left-hand abutment of Donnells dam. The track for the travelling cableway tower is towards the upper part of the picture

The capacity of the plant, which is rather larger than would ordinarily be required for this type of dam, is justified by the need to construct the structure as quickly as possible.

Under the contract the works must be completed by December, 1958, and impounding must have begun some months earlier. There is provision in the contract for the contractor to receive the revenue from the sale of power, less operating costs, for any period before the target date. It is the contractor's plan to finish one year early and it is fully expected that he will do so. Although it will cost more for the contractor to accelerate his programme he will make quite a good bonus and the owners will have water for irrigation one season earlier.

Beardsley

Beardsley dam and power house are to be located four miles downstream from Donnells power house. The dam will be of the rock and gravel type with an impervious core, 280 ft. high and 850 ft. long at crest; it will contain 3,000,000 cu. yards of material. A short tunnel 15 ft. 6 in. in diameter around the dam will be driven for diversion purposes and in the permanent works will become the supply tunnel to the power house, which will be located at the foot of the dam. The capacity of the unit will be 10,500 kW and it will be operated under heads varying from 128 ft. to 264 ft.

Hydrology

The mean annual run-off at a point just below the Beardsley dam was 512,000 acre ft. during 47 years of records; this corresponds to a mean run-off of 790 cusecs during the period. The point of gauging has a drainage area of 318 sq. miles and during the period of record the annual run-off varied from 29 per cent. of the mean to 183 per cent.; the maximum recorded flood was 18,500 cusecs. The drainage area is a high mountainous one and the run-off comes mainly from snow melt during the spring months.

The reservoirs at Beardsley and Donnells will have usable capacities of 78,000 acre ft. and 62,000 acre ft. respectively; the two power plants will have capacities of about 750 cusecs. The plants can therefore operate on base load in the spring and on peak load in the winter while releasing a regulated flow.

The contract is under the direction of Mr. B. Williams, Vice-President, and Mr. E. Shipp, Project Manager for Morrison-Knudsen Company. Mr. B. W. Goodenough is Resident Engineer for the Districts. The Engineers are George E. Goodall Company and International Engineering Company.

Book Reviews

Elements of Hydraulic Engineering. By Ray K. Linsley, Jr., and Joseph B. Franzini. McGraw-Hill Book Company, Inc., New York, Toronto and London. 1955. 582 pp. 352 ff. Price $9.00 or 67s. 6d. net.

The authors, who are respectively Professor of Hydraulic Engineering and Assistant Professor of Civil Engineering at Stanford University, have endeavoured, in this book, to provide the student with a link between the basic course in elementary hydraulics and the specialised technology of the particular branch of hydraulic engineering he chooses. They are at pains to emphasise that there is a unity in hydraulic engineering based on common fundamentals, and they believe that this unity tends to be obscured by a specialised study of any one field.

They therefore set out to give basic information on every branch of hydraulic engineering, on the assumption that the student is already conversant with the theory of fluid mechanics. Thus Part I covers hydrology and American water law, Part II discusses hydraulic structures such as reservoirs, dams, spillways, channels, pressure conduits and hydraulic machinery, and in Part III the various specialised applications are considered, such as irrigation, water supply, power, river navigation, drainage, sewerage and flood control, this section ending with a chapter on multiple-purpose projects. Illustrative worked examples are interspersed through the text, and at the end of each chapter is a bibliography and a series of problems which are left to the student to work out.

From the standpoint of a university or technical college seeking to turn out hydraulic engineers with an all-round knowledge of their subject there is probably much to be said for a book of this kind. On the other hand, to attempt to cover so wide a field in one volume inevitably involves tabloid, and sometimes empirical treatment of any one section, and the professional engineer will need much more detailed analysis than will be found in its pages.

Hydraulics Research 1954. Published for the Department of Scientific and Industrial Research by Her Majesty's Stationery Office. Price 5s. net ($1·25 in U.S.A.), 5s. 2d. post free.

Although the current work of the Hydraulic Research Station at Wallingford, concerned as it is primarily with river and harbour problems, does not impinge directly on hydro-electric development, the Report contains much of common interest. The main investigations during the year related to the behaviour of storm surges in the Thames, silting at Tilbury Docks during spring tides, extensions to Lyttelton Harbour, New Zealand, modifications to the harbour entrance at Southwold, flood relief schemes on the Severn at Shrewsbury and at Maismore, the Bighty Burn culvert in Fifeshire, and the Manaqil syphon spillway in the Sudan.

Work was also carried out on the pilot model of the Severn estuary to determine the possibility of constructing a model to a much larger scale to examine the effects of constructing the Severn barrage. The seaward limit of the present model runs from Barry to a point three miles east of Watchet, where the estuary is 14¼ miles wide. The investigation suggests that the seaward limit of the larger model could be placed some ten miles farther upstream, so that floor space may be saved and the largest practicable horizontal scale adopted.

Geoloski Vjesnik (Geological Bulletin), Journal of the Croatian Institute of Geological Research and of the Croatian Geological Association, Zagreb, Vols. V-VII, 6½ in. by 9 in., 431 pp., 60 ff., 10 plates, 3 maps.

All the articles printed in this publication deal almost exclusively with the geological and geophysical conditions encountered in various part of Croatia. Milan Herak's paper on the Korana region south-east of Slunj contains however an interesting paragraph on the dependence of hydrography upon geological structure. Summaries in German are appended to most articles.

Manual on Rock Blasting: Supplements 1-3. Editor-in-Chief, K. H. Fraenkel. Published by Aktiebolaget Atlas Diesel, Stockholm, and Sandvikens Jernverks Aktiebolag, Sandviken, Sweden, and obtainable from the Atlas Diesel organisation throughout the world. Price in Great Britain from Atlas Diesel Co. Ltd., Beresford Avenue, Wembley, Middlesex, £5 5s. Supplement No. 1, 18s.; No. 2, with binder, 28s.; No. 3, 20s.; all post free at home or abroad.

This valuable compendium on rock blasting, which was reviewed in our August, 1953, issue, is probably the most comprehensive practical textbook on the subject in existence. As our readers may remember, it is printed in four languages—English, French, German and Swedish—which appear in parallel columns, and is in loose-leaf form in a stiff-covered binder to enable additions to be made from time to time.

Supplements Nos. 1-3, constituting the first of these additions, have now been published, and represent so much additional material that with Supplement No. 2 a second binder has been issued and the work rearranged in two volumes. These supplements contain the following papers: No. 1—"Rock Blasting in Great Britain," D. H. Brook and D. Stenhouse; "Bench Blasting in Swedish Limestone Quarries," I. Janelid; "British Commercial Explosives," S. H. Davidson. No. 2—"Drillability of Rock in Rotary Drilling," R. Shepherd; "The Planning of Blasting Operations for Street Excavations and Pipe-Laying Trenches," Hilding Olsson; "The Loading and Transportation of Rock in the Driving of Small Tunnels," V. Wanhainen. No. 3—"The Calculation of Charges for Bench

Blasting and Stoping," U. Langefors; "Permanent Compressor Plants," J. Munck; "Drill Steels with Tungsten Carbide Bits for Percussion Drilling," W. Tenlend and I. Thomaeus.

BEAMA Guide to British Arc-Welding Electrodes. The British Electrical and Allied Manufacturers' Association, 36 and 38 Kingsway, London, W.C.2. Price 5s. net.

This latest edition contains, in addition to the familiar contents of previous editions, a complete new section covering the wide range of special electrodes now available. Information is included on electrodes for welding high-tensile steels, corrosion and heat-resisting steels, cast iron, aluminium and its alloys, bronzes, nickel and its alloys and for hard-surfacing. There are, in addition, notes on the application of these electrodes.

As before, the Guide includes a brief description of the British and American classification systems for electrodes and summaries of the British specifications and Lloyd's Regulations covering arc-welding electrodes. There is also the up to date classified list of mild-steel electrodes showing the British and nearest equivalent American Code Numbers and any Admiralty, Ministry of Transport or Lloyd's Approvals where such apply.

This edition has been completely rewritten, and a new layout adopted to make the information more readily available.

Wasserkraftanlagen, I, Planung, Grundlagen und Grundzüge (Water-Power Plants, Part I, Planning, Fundamentals and Characteristics), by Professor Dr. Ing. Adolf Ludin, in co-operation with Dr. Ing. Wilhelm Borkenstein. Published by Walter de Gruyter & Co., Berlin, 1955, as Vol. 665 of Göschen Collection, 4 in. by 6 in., 124 pp., 60 ff. Price in Germany, paper wrappered, DM.2·40.

After Tölke's "Dams" and Dehnert's "Weirs and Barrages," the Göschen Collection, fully in keeping with its old "short-and-to-the-point" tradition, continues its water-power series with the first instalment of "Water-Power Plants" by another of Germany's foremost experts. There are three main sections: A. Fundamentals; B. Planning and Development; C. Examples of Completed Installations. In A., after the utilisation of water as a source of energy, and basic notions and measurement units have been briefly dealt with, discharge and flow are discussed. B. lists first the various types of hydro plants, and then reviews (section 6) the basic problems arising in the planning of hydro-electric schemes. Sub-section 6-4 is devoted to the various modes of operation: run-of-river, co-ordination and synchronisation in a series of run-of-river plants, long-term storage, and inter-connected systems. The rest of the chapter deals with the economics of water power and with legislation. The final part, which fills almost a half of the whole brochure, contains short but exhaustive descriptions of existing installations. A better selection could hardly have been made, comprising as it does Simbach-Braunau, one of the 17 stages of the Inn development; the Lavamünd pier-type plant (Drau development); the submersible Pitzling plant, on the Lech; foot-of-dam type Génissiat; canal headrace type Deichow on the Bober; Harsprånget underground plant; the Alpine high-head plant Handeck II, and the Schluchsee system. All these names are quite familiar to WATER POWER readers, except Deichow, built in 1933-1936 on a tributary of the Oder to supply Berlin with peak-period energy, and dismantled in 1946. Formulae and mathematical computations are reduced to a strict minimum, and it would be idle to draw a comparison between this neat little brochure and Press's great work previously reviewed in these columns; nevertheless, it is plainly much more than a popular treatise, offers in an uncommonly small volume very good value as a pocket reference book, and will be appreciated by engineers and students who wish to improve their knowledge of technical German terminology. Unavoidably small in size as they are, the illustrations, mostly line, are excellent.

New Projects for Irrigation and Power in India. Issued by the Central Board of Irrigation and Power and available (on sale) on application to the Manager of Publications, Government of India, Old Secretariat, Delhi 8. 1954. 88 pp. Illus.

This booklet has been published with the object of meeting a public demand for information about the many hydro-power and irrigation schemes which are at present under construction or projected in India. Faced with the problems presented by an ever-growing population, the Government is endeavouring by means of large combined power and irrigation schemes to provide power for progressive industrialisation and converting extensive arid areas into crop-bearing fields.

The booklet is popularly written but gives all relevant facts and figures, each scheme being briefly described in relation to the district which it serves. Already more than 52 million acres of land are being irrigated but even so it is estimated that the amount of water used in existing schemes represents a mere 6 per cent. of the total available. As regards power the total potential is estimated to be in the order of 35 to 40 million kW capacity of which less than one million kW has as yet been developed.

Der Wechselsprung mit freier Deckwalze (The Hydraulic Jump with Surface Roller), No. 17 of the Communications on Hydraulic Engineering and Foundation-Soil Research. By Privatdozent Dr. Ing. Paul-Gerhardt Franke, Chief Engineer at the Hydraulic-Engineering Test Institute of the Munich Technical University. Published by Wilhelm Ernst & Sohn, Berlin-Wilmersdorf. 6½ in. by 9½ in., 68 pp., 37 ff. Distributed in the United Kingdom by Lange, Maxwell & Springer Ltd., London N.W.1. Price, paper wrappered, 17s. 2d.

This latest work on the hydraulic jump is based on the results of extensive tests carried out by the author at the Hydraulics Institute of the Bologna University. Part I is devoted to general theoretical considerations; section 6 reviews the methods and formulae previously applied to the calculation of the hydraulic jump, and section 7 deals with the conditions obtaining in a hydraulic jump with surface roller. The results of the tests are analysed in Part II, and Part III deals with the calculation of the hydraulic jump as well as with various patterns of stilling basins. The author attempts to show that all computations are wrong which do not take into account the height loss of the

energy line within the range of the retardation stretch of the jump, thus rejecting all simplified formulae derived from the impulse theorem; this sweeping generalisation is unlikely to remain uncontradicted. Nevertheless, credit must be given for an interesting contribution to a question which is of the greatest interest to the hydraulic engineer and research worker alike, and still awaits the final solution of many problems it involves. The bibliography at the end of the volume lists no less than 151 works dealing either exclusively or principally with the hydraulic jump. The book is very well produced in lithographed typescript on excellent paper.

Concrete Manual. (Sixth Edition.) Published by the United States Department of the Interior, Bureau of Reclamation, Building 53, Denver Federal Center, Denver, Colorado, U.S.A. 7¼ in. × 4¼ in. × ⅜ in. 1955. 491 pp. (including index). 177 ff. Price $2·50.

The fifth edition of this useful manual was issued in 1949 and since that time the technique of concrete making has undergone not a few changes with the advancement of knowledge, particularly in regard to factors which have a bearing on increased strength. In the sixth edition, therefore, full consideration is given to the influence of air-entraining agents and pozzolans, the use of which has extended the applicability of type I cement to a greater range of the Bureau's work. Other new material relates to the precautionary measures which must be taken in the use of calcium chloride where sulphate attack is expected, as test results have shown that the admixture may reduce the resistance of the concrete to this form of attack. Also a new method of protecting concrete pours during frosty weather by means of insulated forms is described. This method of protection has proved to be both effective and economical. A simpler test for checking the variability of mixer performance is presented.

Other improvements concern the procedure to be adopted for the design and adjustment of concrete mixes, the chapter involved (No. III) having been rewritten in accordance with the recommendations issued by Committee 613 of the American Concrete Institute. The new procedure is not only simpler but is also more readily applicable to field use than the procedure previously recommended.

The manual is strongly bound and admirably produced, the diagrams are clear and the text well written; its popularity is evidenced by the fact that no less than 60,000 copies of the five previous editions have been distributed. Having a copy of the manual before us we do not find this fact surprising.

Spiral Casing Construction at Svarthålsforsen

An interesting form of construction has been adopted by Nydqvist & Holm A.B. in connection with three turbines they supplied recently to Svarthålsforsen station on the river Indals in northern Sweden. They are Kaplan machines operating at a head of 15·2 m., and each develops 30,900 h.p. at 107 r.p.m.

A simplified general sectional arrangement of one turbine is given in Fig. 1.

The spiral casing is made of concrete, and for convenience in erection the usual one-piece steel stayring was dispensed with. In the upper part of the casing the loose steel stays were bolted to the foundation ring. At the feet of these stays, sole plates were provided, which were held by foundation bolts and partly grouted in. An advantage of this arrangement was that the loose stays together with the foundation ring could be erected and grouted in simultaneously with the grouting of the spiral casing, and far in advance of turbine erection proper.

The runner, Fig. 2, has a diameter of 5,400 mm., has four blades, and is made entirely of stainless steel. Details of NOHAB Kaplan runner designs were given in our December, 1954, issue, and it suffices here to state that the runner blades can be removed without

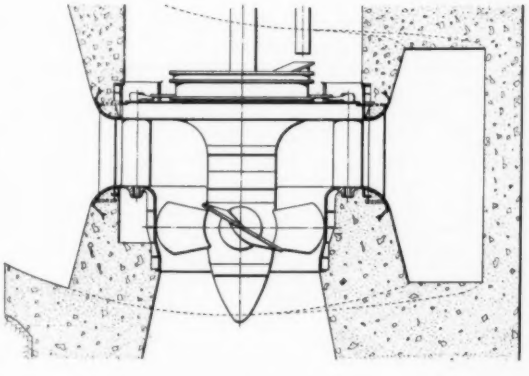


Fig. 1. Section through one of the Svarthålsforsen turbines showing design of spiral casing

Fig. 2. Runner of one of the Nydqvist & Holm 30,900 h.p. Kaplan turbines for Svarthålsforsen

dismantling the rest of the runner. To this end, as will be noted from Fig. 1, part of the discharge ring is removable, enabling a blade to be withdrawn into a recess formed in the concrete.

The conical and curved portions of the draught tube are lined with steel plate.

Hydraulic Tipping Dumper

The Muir-Hill 14B 4½ cu. yard is produced by E. Boydell and Co. Ltd., Old Trafford, Manchester. This vehicle has been designed to combine the advantages of the standard Muir-Hill dumper with a controlled tipping speed which may be varied from 5 sec. up to any desired time.

The body is tipped by two single-acting telescopic rams. These are situated on the outside of the main chassis members to ensure that no twisting arises at the linkage points when traversing rough ground. The hydraulic pump is of the gear type driven through a power take-off from the dumper's main gearbox. After engaging the power take-off level, situated at the rear of the engine cover, the tipping is controlled entirely by the accelerator and clutch pedals; the maximum tipping angle is 65° to the horizontal.

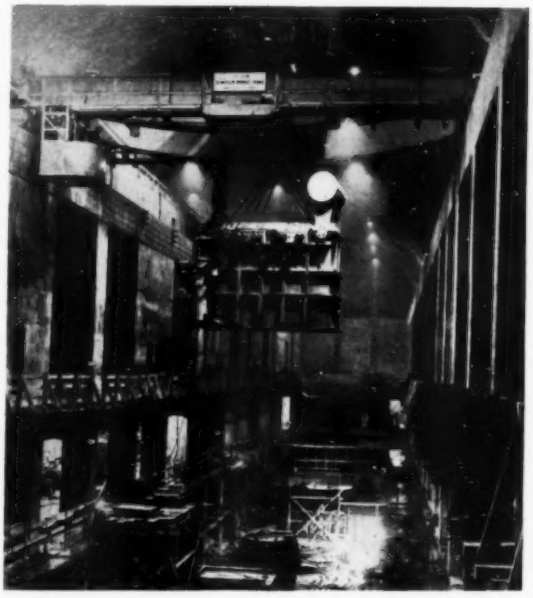
The speed at which a load may be discharged is variable. Control may be maintained for a constant or intermittent flow if desired. Timed figures quoted for both sand and gravel illustrate this feature, a fast tip being achieved in 5 sec. and a slow tip in 3 min. 55 sec.

The body is reset in 5 sec., snubbing springs and chains being fitted between the body and chassis to provide a positive pull-back and initiate resetting of the body by gravity. Designed with a flat level floor and scow mouth, the body unit has been braced to withstand arduous conditions.

The standard body has a rated capacity of 4 cu. yard struck, and 4½ cu. yard heaped. The payload is six tons. A rock type body with a payload of 5 tons 11 cwt. is also available, the cab protection being standard on both types. The unladen weight of the machine is 5 tons 5 cwt. 2 qr. and the overall shipping dimensions give the length as 14 ft. 1 in., width 7 ft. 5½ in. and height (including driver's protection) 9 ft. 9 in.

More Ferranti Transformers for Alcan

Ferranti Limited have been awarded a further order by the Aluminum Company of Canada Ltd. for three 71,000 kVA single-phase generator transformer stepping up to 301,400 V for the famous Kitimat station. These units will form the second 213,000 kVA bank of generator transformers to be supplied by Ferranti Limited for this project. The transformers are unique in that they will have aluminium windings, and it is believed that they will form the largest bank of transformers with aluminium windings in the world.



This order brings the total number of transformers supplied or under construction by Ferranti Limited for the Alcan project to 13 units of a total capacity of 719,000 kVA.

Our illustration shows one of the original 71,000 kVA Ferranti transformers being moved to its cell in the Kitimat station.

Removing River Silt

The River Irwell, a tributary of the Mersey, carries so much silt and gravel that its beds must be cleared regularly to keep it within its banks. The river is fast flowing and subject to rapid rises of water level during rainy periods, when the depth of flow can vary from 1 ft. to 8 ft. in about five hours.

The traditional method of removing silt entailed the use of two machines—a tractor fitted with a 'dozer and also a dragline. The 'dozer was used to pile the

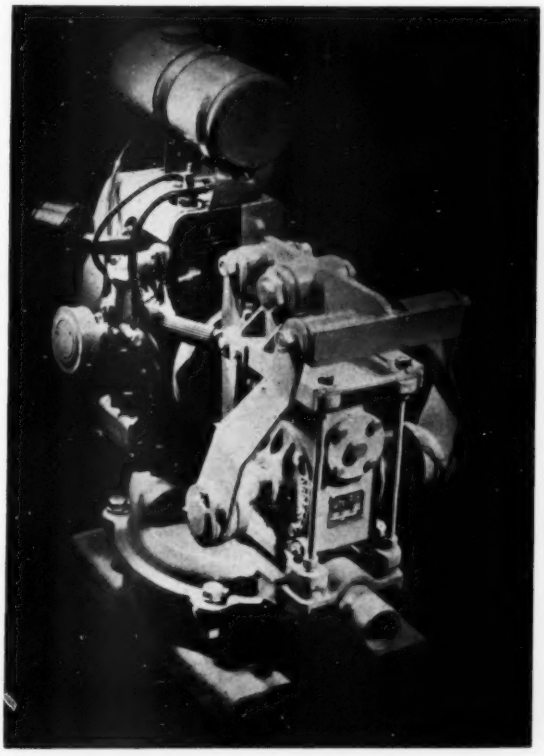
material within reach of the dragline which then lifted it on to the bank.

These two machines have now been successfully replaced by a single Allis-Chalmers Tracto-Shovel, model H.D.9G. (on hire from M. C. Walker, of Westhoughton). This machine is fitted with a 2½ cu. yard capacity bucket and dozes the silt into convenient piles near the bank. It then makes a ramp into the river bed down which the lorries can reverse to be loaded. Where conditions do not permit the lorries to come down to the pile the Tracto-Shovel merely carries the material—2½ cu. yard per trip—up to them. Lubrication of the rollers and idlers in these conditions does not create any difficulty as they only need to be greased once every 1,000 hours; also the track release spring operates in a totally enclosed oil bath. Because of these features, although the tractor spends a large part of its life in water, no ill effects on these assemblies have been detected.

Disc Pump for Dirty Water

A new pump of interest to the civil-engineering contractor has been placed on the market by Arthur Lyon & Co. (Engineers) Ltd., 6, Carlos-place, Grosvenor Square, London, W.1. It is of the disc type and will handle water containing dirt, mud or abrasive material. It will lift 1,200 g.p.h. against a head of 20 ft., and as it weighs only 180 lb. it can be placed on the job by two men by means of the twin carrying handles.

The pump consists of a cast-iron pump chamber, on which is mounted a four-stroke petrol or petrol-paraffin engine driving a worm gearbox, which in turn transmits the motion through a linkage mechanism to the pump spindle. The pump has been designed to run continuously with the minimum of maintenance and lubrication is limited to keeping the gearbox and engine sump topped up with oil. The bearings on the crank spindle are grease packed and need no attention between major overhauls. The bearings at the middle of the top arm and in the pump are of special material which require no lubrication. All other bearings in the connecting linkage are of the rubber bush type and also need no attention. The diaphragm and non-return valve are made of a special grade of rubber interleaved with canvas. The pump spindle and top bearing spindle are made of stainless steel. Two lip-type seals are fitted in the pump to prevent leakage from the pump chamber. The top casting is so constructed that a pocket of air is trapped during pumping which absorbs shock and evens out the pumping rate.



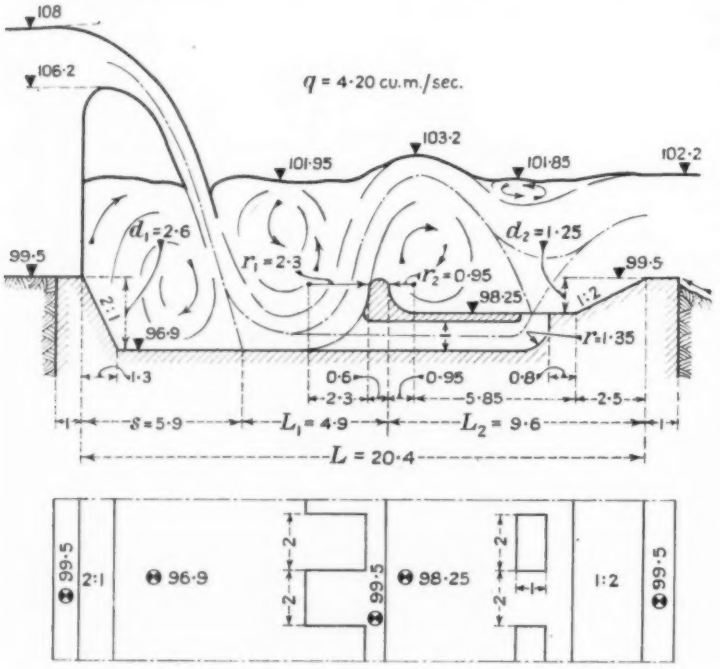
Abstracts from the World Technical Press

High-Speed Building of Earth Dam

Moving at a rate that often exceeds 2,000 cu. yards of fill an hour, the heavy equipment of an Oklahoma contractor is rushing to complete the rolled earth Buford Dam on the Chattahoochee River. The principal purposes of this structure include flood control and power generation, but it will also make an important contribution to navigation on the Apalachicola, of which the Chattahoochee is a major tributary. The main dam and three saddle dykes, together with the many small valleys along the river's course, will create a 20-mile long lake with a storage capacity of 1,250,000 acre ft. and this will be available for flood control, navigation, and power generation. The power house will have an installed capacity of 86,000 kW. The earth-moving job, now about 70 per cent. complete, will be finished in another two to three months. (*Engineering News-Record*, May 5, 1955, p. 34, 3 pp., 7 ff.)

Scour Protection Below Spillways

Exhaustive laboratory tests carried out on small-scale models led the author to the energy-dissipating structure shown in the diagram appended, which, it is claimed, ensures a better protection than conventional apron types against scouring of the river bed downstream of a spillway. The main characteristic of the structure is that the stream-bed flow passes through channels which run under the sill and discharge upwards in front of the baffle pier. Compared to the traditional type of anti-erosion sill, the new design would have the advantage of a much more favourable distribution of flow velocities downstream of the baffle pier, that is to say in the unprotected section of the bed, the maximum velocity occurring at the surface while velocity towards the bottom decreases to a minimum; besides, energy dissipation is said to be higher than in the conventional design. This would result in a substantial reduction of scouring in height and depth downstream of the baffle pier, not to mention lower costs, since the stretch of the natural river bed requiring protection would be considerably shorter. (Jerzy Sielski, *Archiwum Hydrotechniki*, Vol. 1, No. 1, p. 5, 50 pp., 31 ff.)

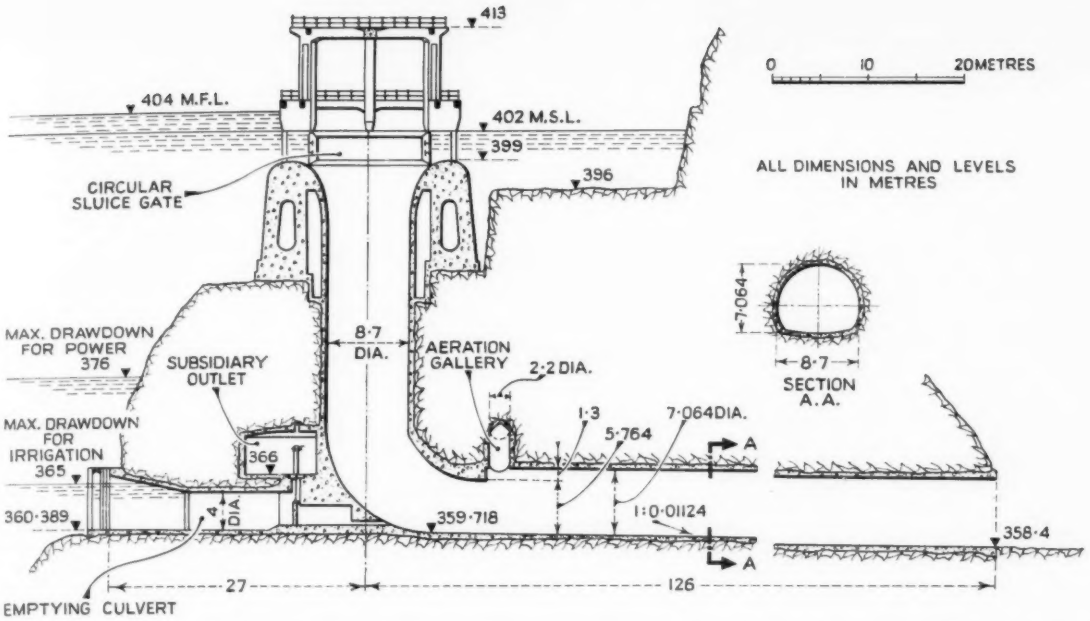


Short-Circuit Tests with High-Speed Reclosing

This is a detailed account of the short-circuit and high-speed reclosing tests effected on the 220 kV Mettlen-Lavorgo transmission line, before it was put into operation. The neutral of the system is earthed. These tests established the perfectly correct working of the distance relays, high-speed pneumatic circuit breakers, and reclosing equipment. The residual arc still burning after the unipolar breaking of the earth was extinguished after at most two cycles. After dead intervals exceeding 0·22 sec. with three-phase breaking and 0·45 sec. with single-phase breaking, there was no recurrence of the arcing, and energy transmission suffered no interruption. The dependability and accuracy displayed throughout the tests by the circuit breakers, high-speed distance relays and reclosing apparatus was particularly remarkable. (F. Schär & P. Beltensperger, *Bulletin de l'Association Suisse des Electricien*, Vol. 46 (1955), No. 7, July, 1955, p. 762, 11 pp., 15 ff.)

Cellina Development

In spite of its moderate gradient, the Cellina river, a right-bank tributary of the Meduna, lends itself fairly well to the setting up of hydro-electric plants, owing mainly to abundant precipitation; the lack of glaciers and an extensive deforestation cause wide discharge fluctuations, so that a large regulation storage is an absolute necessity. So far, the utilisation of the river had been restricted to the Malnisio, Giais and Partidor run-of-river plants, built in 1905, 1908 and 1919 respectively, and producing together an average of 100 million kWh per annum. Following extensive investigations and recent agreements with the Cellina-Meduna Reclamation Board, the Società Adriatica di Elettricita (SADE) have worked out a programme which will complete the Cellina Development, increase ultimately the aggregate yearly production to 450 million kWh and capacity to 200 MW and leave an adequate scope to badly needed irrigation. The first phase of this programme comprises the three new plants Barcis, S. Foca and Villa Rinaldi, put into operation at the beginning of 1954, and des-



cribed at length in this article. Barcis, upstream of Malnisio, with a reservoir which at present forms the head of the whole development, utilises a head of 59·4 m., while the run-of-river plants S. Foca and Villa Rinaldi, downstream of Partidor, operate the head between El. 191·6 and 85·87 m. The total head utilised by this chain of old and new plants is 316·13 m., with a catchment of 424 sq. km., a regulating storage capacity of 20 million cu. m., and an average production of 220 million kWh. The later successive phases of the programme will comprise works connected in part with the Piave-Boite-Maè-Vajont hydro-electric system, and the additional capacity of regulation storage provided to some extent by the Vajont reservoir will increase the aggregate production capacity by 230 million kWh by means of four further plants in the upper catchment area, and one downstream of the present chain. The three new plants now in operation are already adapted to the future utilisable discharges or designed for later enlargement, while the older plants are to be either wholly or partly reconstructed. Renovation work has already started at the Malnisio dam, which has undergone some alterations to recover part of its storage capacity for use as a balancing agent between Barcis and the plants further downstream. (*L'Energia Elettrica*, Vol. XXXII, No. 7, July, 1955, 17 pp., 20 ff.)

More High-Speed Tunnelling

Using rounds 10 ft. deep that effected an average advance of just over 9 ft., crews of the Kaiser-Walsh-Perini-Raymond group of contractors established what is claimed to be a new world's record by driving 402 ft. of the Ecumbene-Tumut Tunnel in a six-day week; the tunnel, 14 miles long and 24 ft. in excavated diam., is part of Australia's Snowy Mountains Development. It will be driven from three headings, of which the first to get under way is the one in which this achievement was made, the heading then being about 3,000 ft. from the portal.

In addition, the contractors will drive in two directions from a junction shaft situated about 10 miles along tunnel line from the Ecumbene portal. This shaft is now 130 ft. deep and must reach 300 ft. before tunnelling can be started. The previous generally accepted record of 363 ft. was set in 1953 on the Pit 4 project of Pacific Gas and Electricity Co. in California. (*Engineering News-Record*, Vol. 154, No. 24, June 16, 1955, p. 24, 1 f.)

Note: A stretch of 428 ft. in a 10 ft. 6 in. bed-width tunnel was driven on one heading during the week ending December 19, 1954, and represents the British and European record; this was set by The Mitchell Construction Company, Peterborough, on one of the Breadalbane contracts, North of Scotland Hydro-Electric Board.

The Messina Crossing

Sicily, which for many years depended almost exclusively upon local thermal plants for its supply of electricity, will shortly be fed from the mainland system of the Compagnia Nazionale Imprese Elettriche through an overhead line carried across the Straits of Messina by two gigantic lattice towers which present the following characteristics:

Height	224 m.
Base area	35 × 35 m.
Weight each	450 tons

They are designed to withstand winds of up to 150 km. per hour, a pull of 25 tons, and earthquakes up to 10 degrees Mercalli. The mainland tower is erected on a rock plateau 166·4 m. above the water, and the island tower only 10·2 m. above sea level, on a sandbank which runs out under water up to 233 m. into the Straits; this means a difference in level of 156·2 m. between the two towers. The cross-shaped baseplate of each tower consists of a solid block of ferro-concrete, which required 2,600 cu. m. of concrete and 350 tons of steel on the mainland, and 4,300 cu. m. of concrete and 490 tons of steel on the island; this wide difference in cubage is due to the fact that the island baseplate rests at each end on a pillar 9 m. by

9 m., sunk caisson-like 20 m. deep into the sandbank; the towers were shop-welded into large sub-assemblies and subsequently assembled by bolting on site. Each tower is provided with a 500 kg. capacity lift as well as with an inspection staircase. The horizontal cross-arm, no less than 75 m. in length from end to end, is to carry four cables, and the extensions at the top, one each, so that there will be on either side a triangular a.c. system with conductors 25 m. apart; the conductors are simply suspended to the cross-arm and extensions by means of ropeway-type stirrup hangers. The total length of the cable across the Straits is 5,051 m., and the net span between towers 3,653 m. Measured from the top of the mainland tower, the cables have a sag of 292·4 m., their minimum height above sea level at the lowest point being 70 m. The cable stretcher, sited on the island, follows the practice applied to the contact wires of railway lines, and uses counterweights to hold the cables under a constant pull of 25 tons. The steel-aluminium cables have the following characteristics: Diameter, 27·8 mm.; cross-section, 44·7 sq. mm. aluminium plus 311 sq. mm. steel = 355·7 sq. mm.; weight per metre, 2·8 kg.; breaking load, theoretical 60·9 tons, effective 56·4 tons; resistivity, $255/10^6$ per metre at $0°C$. The cables have 19 stranded wires, the central wire being surrounded by the remaining 18 in two layers between which metal continuity is ensured by six steel wires 2·1 mm. diameter; each strand consists of an aluminium core 1·73 mm. diameter and six steel wires 1·8 mm. diameter. At the outset, the line is to consist only of the four conductors suspended to the cross arm, one conductor acting as a standby, with a transmission capacity of 50,000 kW at 150 kV; when the voltage is increased to 220 kV, the capacity will rise to 150,000 kW and, after the addition of the two top conductors, to 300,000 kW. (H. Lutz, *Wasser- & Energiewirtschaft*, Vol. 47, No. 3, March 1955, p. 39, 6 pp., 8 ff.)

Draft-Tube Design in High-Head Francis Turbines

This article first demonstrates how the pressure at the outlet of turbine runners can be ascertained from the design characteristics of the runner and draft tube, the penstock layout, the operating data and the suction head. For a given runner and draft tube, the upper limit of the suction head is determined by the occurrence of cavitation phenomena; and the extent of this suction head can be computed from an empirical formula or from various equations deduced by various authorities. The figures thus obtained are quite reliable in the case of small units operating at normal heads, but model tests must be resorted to when dealing with large high-head turbines. The finally-selected elevation at which the runner should be placed must ensure a pressure head in order to ensure undisturbed running, and act as a safeguard against cavitation as well as against turbulence in the draft tube during governing operations. For a given penstock layout, the draft-tube design, the turbine closing time and graph, the profile diagram of the runner, it is possible to calculate accurately the pressure drop which occurs at the upper cross-section of the draft tube during a load decrease; this is also shown in instances where the turbine is fitted with a relief valve. To restrict the pressure drop as much as possible, a draft tube of given length and energy-conserving capacity must have the shortest possible transition from the vertical to the horizontal cross-section. By the same method it is possible to compute the forces put into operation while the unit is being put under load, and to determine the design of the bearings of geared units. (Dr. Ing. H. Netsch, *Die Wasserwirtschaft*, Vol. 45, No. 9, June, 1955, p. 22, 6 pp., 5 ff.)

Swiss Tour of North Italian Plants

This year's annual excursion of the Swiss Water Association began in Milan on September 3, and ended in Venice eight days later, taking in its stride some of the north-eastern districts of Italy richest in hydro-electric developments. This article, intended as a technical guide, gives a description of some of the plants included in the tour: the Alto Chiese Group (Bissina and Boazzo dams, Cimego power station); the Sarca-Molveno installations, with the S. Massenza plant housed in a cavern 188·22 m. in length; the S. Giustina-Mollaro plant of the Società Edison; the Fedaia dams, among which the 300 m. long earthfill dam fitted with an impervious diaphragm of the new ICOS type (WATER POWER, July, 1954, p. 281); the Pieve-Boite-Maè-Vajont Group, with Pieve di Cadore and Soverzene; the Ala power station, and the Medio Adige works, with their extensive systems of supply canals, 46·5 km. in aggregate length, which comprise a 210 m. long aqueduct across the Valle Tasso. (G. A. Töndury, *Wasser- & Energiewirtschaft*, Vol. 47, No. 8, August, 1955, p. 175, 26 pp., 37 ff.)

Tubular Framework for Open-Air Substations

Lighter weight, lower cost of protective coating, standardised components, easier erection: such are the advantages claimed for the tubular framework adopted by the Lausanne Corporation for their latest suburban substantions which present the following main characteristics:

	W. Suburbs (built 1952)	Sébeillon (built 1955)
Transformer rating	50 kV/6·5 kV	50 kV/6·5 kV
Area covered by framework	28 × 16·5 m.	47 × 28 m.
Maximum height	9·5 m.	8·5 m.
Side pull on yokes per conductor	400 kg.	500 kg.

The experience gained from the older structure led to the application of various improvements at Sébeillon. For instance, all the yoke ends welded to columns are identical. Joints are effected by interlocked sockets fastened by thrust screws. The yokes themselves consist of tubes varying in thickness according to span, on to which are welded ears holding the conductors. Erection was also easier and required considerably less time. The columns, instead of being sunk direct into the concrete platform, are anchored by long bolts on baseplates. After the baseplates have been placed in position, adjusted and concreted, the columns and yokes are assembled into portals on the floor, and the portals are hoisted into position and bolted on to the baseplates. All columns on the one hand, and all yokes on the other, have the same inside diameter, and, owing to the small thickness of the tube walls, jointing by welding can be effected in the shortest possible time. As to cost, in spite of the higher unit price of tubes, it is claimed that the new tubular framework can successfully compete with the traditional lattice assemblies made of standard steel sections. (Jean-Cl. Piguet, *Bulletin Technique de la Suisse Romande*, Vol. 81, No. 16, 6.8.1955, 3 pp., 3 ff.)